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CITY OF CALGARY FLOOD STUDY

VOLUME ONE

BOW RIVER REPORT

MAY 1973

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WATER RESOURCES DIVISION

CITY OF CALGARY FLOOD STUDY

VOLUME ONE

BOW RIVER REPORT

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montreal engineering company, limited

1500 ONE PALLISER SQUARE, 125 - 9th AVENUE S.E.,
CALGARY, ALBERTA, CANADA T2G 0P6.

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14 May 1973

Mr. J.L. Reid
Supervisor, Hydro-Electric Development
Water Resources Division
Alberta Department of the Environment
10040 - 104 Street
Edmonton, Alberta

Dear Mr. Reid:

We are pleased to submit our report on the Bow River which forms part (Volume One) of the City of Calgary Flood Study. The report on Fish Creek, which was included in the Study, was submitted to you on November 2, 1972.

This report deals in the main with lands adjacent to the Bow River from 37th Street, N.W. to the confluence of the Bow with Fish Creek. Salient information on the Bowness reach of river, which was examined in depth in the report on the Bowness Flood Study (April 1971), is included so as to provide a comprehensive view of the flood hazard along the whole reach of river throughout the City.

The appropriate course of action to alleviate potential flooding will comprise a mix of modest engineering measures coupled with firm management of developments in the flood plain. Accordingly, much of the study effort has been focussed on applying the two district concept of flood plain management to all flood prone areas along the river. A complete set of maps showing the recommended districts together with accompanying development guidelines is presented in this report.

We trust that you find this report satisfactory and we look forward to discussing it with you in due course.

Yours very truly,

G.V. Eckenfelder
Vice-President

D.R. Nancarrow
Manager
Water Resources and Environmental Division

PREFACE

The City of Calgary Flood Study is being undertaken in accordance with an agreement between the Minister of the Environment of the Province of Alberta and the City of Calgary which was executed on 17 September 1971. Authorization to proceed with the study was given by Mr. J.L. Reid to Montreal Engineering Company, Limited on 26 May 1971.

The objective of the study as stated in the terms of reference is:

> *"to study and report on potential flood damages and possible remedial measures concerning lands adjacent to the Bow River from 37th Street N.W. to 1,000 feet below the confluence of Fish Creek with the Bow River. The study will also include lands adjacent to Fish Creek from the Sarcee Indian Reserve downstream to its confluence with the Bow River. The study will recommend the optimum course of action which should be taken to alleviate the potential flood hazard with particular emphasis on the management of developments in the flood plain."*

This study is the latest in a series on the flood hazard which have been undertaken by the Province and City in recent years. Of particular importance was the study executed by the Company in 1967 and 1968 in which the flood plain through the City was delineated, the magnitude and frequency of flooding was appraised and the need to control future development in the flood plain was emphasized. The results of this study were presented in a report entitled "Flood Plain of Bow River in the City of Calgary" dated February 1968. The 1968 report provided a sound basis from which to proceed with more detailed studies of priority areas. Reports have been prepared on St. George's Island, Prince's Island, the Elbow River and Fish Creek.

The 1968 report identified the Bowness Area as one of the most vulnerably situated areas along the Bow River and, in April 1971, a report on this area entitled "The Bowness Flood Study" was completed. The study of the Bowness Area was the first in which potential flood damages were assessed in monetary terms and in which the benefits and costs of remedial measures were analyzed in some detail. It revealed that many of the more promising measures for counteracting the flood hazard in Bowness would benefit the whole of the flood plain. Consequently, certain of the recommendations made were tentative pending study of the flood plain as a whole. This study follows on directly from the Bowness study in order to explore in greater detail and confirm the tentative recommendations made in the Bowness Report.

The report on the City of Calgary Flood Study is contained in two Volumes and one Appendix. Volume One entitled "Bow River Report" and Volume Two entitled "Fish Creek Report" respectively deal with lands adjacent to both streams. They contain descriptive and analytical material, and flood plain guidelines and maps required to manage development in the flood plain.

The Appendix to the report contains details of the hydrologic investigations which have been carried out to confirm the flood potential through the City and details of other study components.

Execution of the City of Calgary Flood Study has been greatly facilitated by the co-operation and assistance given by Mr. C.D. Howarth, City Engineer, Mr. J. Pascoe, Manager of Urban Development and other officials from the City of Calgary, notably from the Planning Department. In addition, data made available by Alberta Water Resources Division have helped reduce the extent of field survey and reconnaissance necessary to bring the study to fruition. Dr. Ian Burton, University of Toronto, has advised on non-engineering aspects of the work.

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

1. This study is concerned with potential flooding along the 24 mile reach of the Bow River from 85th Street N.W. downstream to 1,000 feet below Fish Creek and along Fish Creek. (Fish Creek is dealt with in a separate volume of this report.) A repetition of the flood of 1897, with a peak flow of 80,000 cfs above the Elbow River and a return period of approximately 1 in 70 years, would result in some 2,500 dwellings and 350 commercial and industrial establishments being directly affected by overland flows. There is also a possibility of peak flood flows substantially greater than those experienced to date. Clearly potential flooding along the Bow River poses a problem of significant dimensions.

2. Based on present values, the average annual damage from flooding throughout the City will, in the long-term, amount to about $400,000. Potential damages to residential properties alone represent almost 50 per cent of this figure. Damage from a single flood of 80,000 cfs would be about $10 million. The damage estimates have been made on the assumption of idealized flow conditions, e.g. no blockage of bridges or extraordinary high water levels resulting from rapid failure of stream banks.

3. Of a total flood plain area of 5,278 acres at a flow of 80,000 cfs (110,000 cfs below the Elbow River), some 4,156 acres are in open-space use. Consequently, if this area were developed in a manner similar to presently developed areas, the degree of the potential flood problem through the City could be greatly magnified. Thus, the need to deal with the problem in an effective manner is well established.

4. There are two fundamental approaches for alleviating the potential problem; one based on the control of floods through large-scale engineering measures such as reservoirs and dykes, and the other based on the control of land-use in the flood plain through administrative measures such as zoning ordinances, i.e. flood plain management. While these approaches are not mutually exclusive and, in fact, are generally complementary, one approach will usually predominate depending on the economics of the situation. The lack of economically feasible and socially acceptable large-scale engineering possibilities points strongly to the need for flood plain management in the City of Calgary. The appropriate strategy will comprise a mix of modest engineering measures coupled with firm management of developments in the flood plain (see Item 6).

5. A two district concept of flood plain management has been applied to lands adjacent to the Bow River (and Fish Creek). This results in 1,585 acres immediately adjacent to the river being designated as a Floodway District and 3,693 acres being designated as Flood Plain District. The Floodway District would be reserved for open-space use, such as parkland,

and, in general, no further development of a structural nature would be permitted. Development would be permitted in the Flood Plain District provided that it conforms to certain structural requirements. Recommended guidelines applicable to each district are presented.

6. Opportunities to construct large-scale engineering works to control summer flooding of the Bow River are limited. Moreover, the opportunities that do exist are uneconomic (in terms of potential damages avoided) and, in certain instances, may be socially untenable.

Flood Storage

Of the existing reservoirs only Ghost offers an opportunity for reduction of the flood peak in the City of Calgary. Whilst even in the case of Ghost, the opportunity is limited it has been concluded that supplementing the existing flood forecasting procedures with recently developed forecasting techniques holds promise and may permit a greater degree of flood control without compromising power, irrigation and recreation demands on the reservoir.

It must be stressed, however, that only a relatively small reduction in the overall potential hazard in Calgary is possible.

The construction of new storage reservoirs for flood control is clearly uneconomic and should be dismissed from further study.

Dykes

With the possible exception of a scheme to protect the Pearce Estate, Inglewood Area, dyking as a measure to provide a reasonable degree of protection to developed areas is not a feasible proposition along the Bow River. The costs of the various dyke schemes evaluated during the study would generally be several times the benefits achieved in terms of flood damages prevented, and, moreover, there could be opposition by residents of the flood plain and others because of the attendant loss of aesthetic values.

Major Channel Improvements

Dredging or a general widening of the river channel to reduce flood levels is not economically feasible and is undesirable from the standpoint of channel stability and the detrimental aesthetic and environmental impact such measures would have. This alternative should be dismissed from further study.

7. A number of channel improvements involving the removal of severe constrictions to flow are recommended for implementation. A programme of improvements costing in the region of $985,000 (excluding works below Crematorium Hill) is recommended for implementation at the earliest opportunity. The principal improvements required are:

- the bend in the river below Crematorium Hill (this work is already underway);
- in the vicinity of St. George's Island involving in the main the removal of the landfill at the south end of the South St. George's Island Bridge;
- on both banks upstream and downstream of Langevin Bridge;
- to the south bank alignment downstream of Crowchild Bridge;
- to both banks in the vicinity of Cushing Bridge.

8. The extent and effectiveness of emergency action in anticipation of a major flood is largely dependent on how early the warning is given. Supplementing the existing forecasting system with recently developed techniques involving a computerized watershed simulation model will facilitate emergency action by advancing the time at which an accurate forecast and realistic warning can be given. Progress in this direction has been made recently by the Water Survey of Canada.

It is recommended that a flood forecasting centre be established. Step-by-step procedures for the issuing of flood warnings and action by the City should be drawn up.

9. When compared to the critical slide area below Crematorium Hill (which is presently being stabilized) and the slide area below Wildwood Drive which has been recommended for detailed investigation, other potential slide areas adjacent to the river appear relatively stable. However, it is recommended that two active slide areas downstream of Gallelli's Bridge should be monitored in detail prior to development on adjacent flood plains or subsequent to the passage of a flood if erosion of the bank is significant.

10. Using the flood plain district maps as a guide, it is recommended that:

(i) No mining for gravel or stockpiling of material be carried out in the Floodway District.

(ii) Subject to other regulations not pertinent to flooding, mining be permitted in the Flood Plain District provided that:

- a buffer zone of undisturbed material with a minimum width of 100 feet be left between the channel and the mining operations;

- a stable dyke comprising cobbles or rock be built along the buffer zone to an elevation compatible with the step limit elevations shown on the recommended district maps.

11. There is a pressing need to provide bridges which will remain in operation during a flood of 80,000/110,000 cfs, especially along the downtown reach. It is recommended that the net width of future bridges be the width of the Floodway District and that low chord elevations be some 4 feet above the step limit elevations shown on the recommended flood plain district maps. The approaches to such bridges should not be lower than the step limit elevations. It should be noted that the existing Louise, Centre Street, Old Langevin, Baines and Cushing Bridges do not meet one or both of these criteria.

12. A public information programme is needed to gain public acceptance of the measures which have been recommended and give the Province and the City a clear mandate to proceed with their implementation.

13. In summary, the strategy to deal with the potential flood hazard in the City of Calgary in an optimum manner which has evolved during the study comprises the following main elements:

(i) The adoption of statutory regulations for controlling development in the flood plain;

(ii) The establishment of a flood forecasting centre by a Federal or Provincial agency and the establishment of step-by-step procedures for the issuing of flood warnings and action by the City;

(iii) Channel improvements involving the removal of severe constrictions to the passage of flood flows;

(iv) A public information programme.

TABLE OF CONTENTS

	PAGE
Letter of Transmittal	(i)
Preface	(ii)
Findings, Conclusions and Recommendations	(iv)
Table of Contents	(viii)
PART 1 INTRODUCTION	
PART 2 POTENTIAL DAMAGES	
PART 3 MEASURES TO DEAL WITH THE FLOOD HAZARD	
PART 4 RECOMMENDED PLAN	
PART 5 GUIDELINES AND MAPS SHOWING FLOODWAY AND FLOOD PLAIN DISTRICTS	

PLATES

PLATE		PAGE
1-1	Bow River in Calgary	1-3
1-2	Water Surface Profiles at Selected River Flows 85th St. N.W. to 45th St. N.W.	1-16
1-3	Water Surface Profiles at Selected River Flows 45th St. N.W. to 4th St. N.E.	1-17
1-4	Water Surface Profiles at Selected River Flows 4th St. N.E. to 48th Ave. S.E.	1-18
1-5	Water Surface Profiles at Selected River Flows 48th Ave. S.E. to 110th Ave. S.E.	1-19
1-6	Water Surface Profiles at Selected River Flows 110th Ave. S.E. to Fish Creek	1-20
1-7	Upper Study Reach - 85th St. Bridge to Bonnybrook Bridge	1-21
1-8	Lower Study Reach - Bonnybrook Bridge to Fish Creek	1-22

1.1 HISTORICAL BACKGROUND

Fort Calgary was established by the Northwest Mounted Police on the low ground at the confluence of the Bow and Elbow Rivers in 1875. In the short span of twenty-seven years to 1902 three major floods occurred which were greater than any that have since been experienced. The flood of 1897 was reported to be the most destructive ever witnessed in the Bow River Valley, although there is evidence that the flood in 1879 may have been as great. The peak flow of the flood in 1902 was appreciably less than the peak flows of the two earlier floods, but nevertheless damage was reported to have been extensive.

In contrast to these early years of settlement at Fort Calgary, there has not been a major summer flood on the Bow River since 1932. Thus, whilst the early residents had good reason to recognize the dangers of building in the flood plain and were able to plan accordingly, there has been little incentive to take the hazard into account in recent years. It should be noted that significant summer flooding in Calgary will occur when flows in the Bow River (above the Elbow) are of the order of 20,000 to 25,000 cfs. Since 1932, the maximum instantaneous flow has not exceeded 23,000 cfs.

In the 1968 report entitled "Flood Plain of Bow River in the City of Calgary" and again in this report, it is stressed that there has been no significant change in meteorological patterns or hydrological conditions since the early years of the century. Major floods are just as likely to occur now as then. However, as demonstrated by the studies and investigations initiated by the Province and City in recent years, the situation is receiving close attention and determined efforts are being made to develop an appropriate course of action.

Prior to the 1968 report which dealt in the main with the summer flood potential, it was winter flooding caused by ice jams which was of primary concern to the citizens of Calgary. In the years immediately after the end of World War II, winter inundation of serious proportions occurred in the City, notably in the Bowness, Hillhurst and Sunnyside areas. In recent years, the risk of winter inundation has been reduced. The main reasons for the reduced incidence of winter inundation in the years since the mid-1950's are, listed in order of effectiveness, as follows:

(i) The construction in 1954 of Bearspaw Dam whose forebay traps slush ice in the river downstream of Ghost Dam.

(ii) The reduction in monthly winter flows in the river due to the lesser reliance now being placed on the hydro-electric plants on the Bow above Calgary for meeting overall power demands.

(iii) The dykes, notably through the central part of the City, which prevent surface overflow.

(iv) The construction in 1959 of the Ice Pack Anchorage downstream of Louise Bridge. The anchorage forms an ice jam in the river at an optimum location although it should be noted that its effectiveness has been diminished since its inception by partial infilling with gravel carried along by the river.

While the works described have been extremely successful in reducing the frequency of winter flooding, especially along the Bowness reach of the river, the possibility of such flooding remains as witnessed during the winter of 1966 when the dykes protecting Sunnyside were brimful. However, this study has concentrated on potential summer flooding with the knowledge that the hazard it poses is much greater and that measures taken to alleviate this hazard will also alleviate the effects of winter floods.

With respect to protection against winter flooding, it should be noted that much of this protection would be lost in the event of a summer flood similar to that which occurred in 1932. The dykes which protect extensive reaches of the downtown area of the City are often of an emergency nature, oversteep and inadequately protected to withstand the high velocities of a major summer flood. Moreover, the Ice Pack Anchorage which is effective along the reach of the river from Louise Bridge to Centre Street Bridge would be infilled completely by the movement of bed material in the river. The potential damages to the works constructed to provide winter flood protection will be discussed in subsequent parts of this report.

1.2 THE STUDY AREA

The study area embraces flood plain lands adjacent to the Bow River and Fish Creek in the City of Calgary. In this volume of the report only, the Bow River flood plain is discussed. The flood plain associated with Fish Creek is dealt with in Volume Two. The Bowness reach of the Bow River from 85th Street N.W. to 37th Street N.W. was studied in depth in an earlier report. However, in order that this report can present an overall view of the flood hazard along the Bow River, the Bowness reach is included in the study area of the City of Calgary Flood Study. The study area is shown in Plate 1-1.

121 LAND USE

The Bow River enters the City of Calgary at the 85th Street N.W. Bridge and flows in a generally easterly direction for a distance of some 12 miles to the Western Irrigation District (WID) Dam. Immediately downstream of the dam, the river flows in a southerly direction for a further 12 miles before leaving the City at its confluence with Fish Creek. During its passage through the City, the Bow is joined by two tributary streams of significant size, namely, the Elbow River and Nose Creek with respective drainage areas of approximately 490 and 303 square miles.

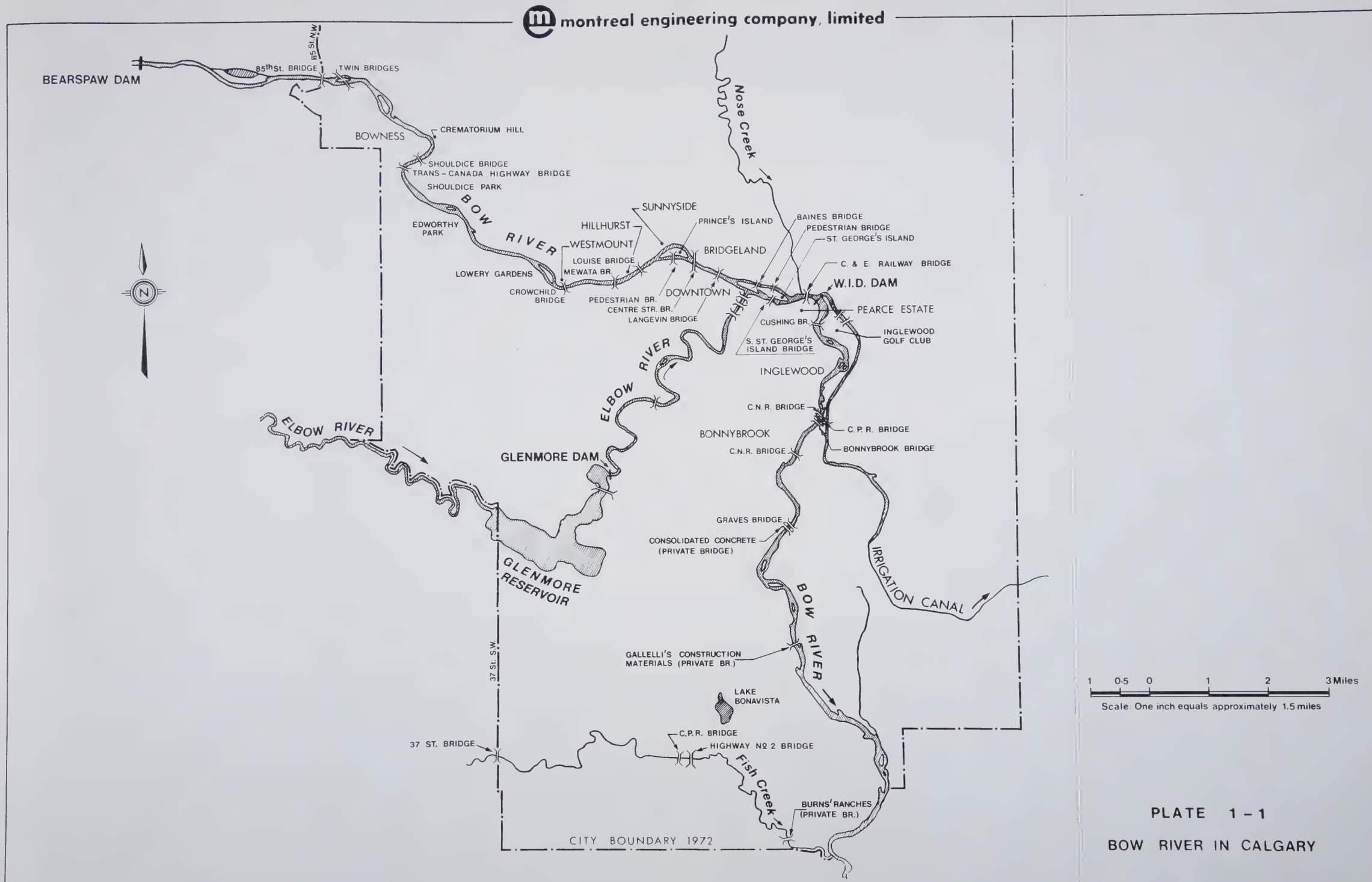

PLATE 1 - 1

BOW RIVER IN CALGARY

The character of the river and the extent of development on adjacent flood plains serve to divide the river into two distinctly different reaches. Along the upper reach from 85th Street Bridge downstream to Bonnybrook Bridge, the river flows between fairly well defined banks and few flood channels are visible. With exceptions, such as Shouldice Park, Lowery Gardens, Prince's Island, Pearce Estate and Inglewood Golf Club, the flood plain along this reach has been extensively developed, primarily for residential and transportational use with some commercial and industrial use. Along the lower reach from Bonnybrook Bridge to Fish Creek, the channel is more braided and sinuous with poorly defined banks. Little development of a constructional nature has occurred along this reach to date and the flood plain is used mainly for agricultural activities and gravel mining operations. Most of the flood plain land along the lower reach is designated as a Direct Control District or as an Agricultural (Future Industrial) District.

Active erosion of the river banks and channel is apparent at many locations throughout the City, especially where gravel operations and landfill into the original channel of the river have occurred. This erosion has resulted in the formation of many unnatural bars and islands which in turn encourage further erosion. Many of the bars and islands are well vegetated, a testimony to the lack of major floods in recent years.

As a result of the development in the flood plain and the growth of trees on bars and foreshore along the upper reach, the ability of the river channel and overbank areas to handle flood flows has been significantly reduced over the years. Two factors which have led to this reduction are the several bridge waterways of inadequate section and landfill into the main channel. The most prominent constrictions to the passage of a flood through the City are:

- the slide debris in the river channel below Crematorium Hill. This situation is being remedied presently but even upon completion of slope stabilization works, the bankfull width at the narrowest section will be less than 350 feet.

- the northbank landfill approximately 1/4 mile downstream of Crowchild Bridge and the constriction imposed by an abandoned water intake on the south shore.

- the southbank landfill at Langevin Bridge.

- the southbank landfill for a carpark at South St. George's Island Bridge.

- landfill on both banks immediately downstream of Cushing Bridge.

The upper reach of the flood plain contains many of the older buildings in the City and many of these are being renovated or replaced by more modern structures. In Bowness, rebuilding and redevelopment has resulted in several new houses, especially along the riverbank, and in the low-lying areas of Hillhurst and Sunnyside intensive redevelopment is

apparent as many of the older, wood-frame, single family residences are being replaced by 3 or 4-storey apartment complexes with basement living quarters. Redevelopment of low-lying land is also occurring in the downtown area east of Centre Street. Several multi-storey buildings have been constructed in this area in recent years and these have been accompanied by a general raising of the original grade levels. The advent of the new Langevin Bridge is expected to increase the pace of redevelopment in this area. Thus, the investment in presently developed flood plain areas of the City is on an upward trend and this situation is being compounded by additional pressures to develop other known flood plain lands which have hitherto remained in open-space use.

122 PERCEPTION AND ATTITUDE

The perception and attitude of flood plain occupants towards the flood hazard has been probed by two surveys; one carried out in July 1970 obtained the views of residential property owners in the Bowness area and the other carried out in October 1971 obtained the views of the managers of commercial and industrial properties in the remainder of the flood plain. The surveys revealed that, whereas the awareness of past flooding is high mostly as a result of the winter ice flooding which occurred in late 1951 and 1952, the expectation of future flooding is low. Most respondents appreciated the role of Bearspaw Dam and the dyking system in reducing the likelihood of winter flooding. However, they also assumed that the measures undertaken to counteract winter floods would also afford protection against summer floods.

Not surprisingly, in view of the low level of expectation of future flooding, few respondents to the surveys had any ideas on what could be done to reduce flood damage to property. Many had not previously thought about how they would respond to a flood warning. When suggestions were made, they were generally received with appreciation and all respondents evinced some interest in the things they might do with outside help or advice.

Various alternative measures for counteracting the hazard were discussed with the respondents and this revealed potentially strong opposition to the construction of dykes in the Bowness area. Most respondents, however, expressed a willingness to be advised about the flood problem and it was concluded that opposition to sensible land-use planning and building restrictions might not be strong.

The survey of commercial and industrial property managers indicated that most managers were also extremely satisfied with their present locations in the flood plain, mainly from the transportational standpoint. Several expressed the opinion that expansion or relocation of their facilities was conceivable in the near future and, in a few instances, it was noted that this would take place on land adjacent to their current operations.

Other reaction to the potential flood problem was obtained from the written submissions and verbal presentations to the public hearing of the Standing Policy Committee on Operations and Development, City of Calgary, held on 7 March 1972. The hearing was called to obtain the views of residents and property owners in the Bowness area towards proposed guidelines for managing future developments in the flood plain. Several concerns were expressed, most notably with regard to possible property devaluation and the existence of the flood hazard. It was the Committee's direction and instruction that the concerns expressed by taken into account when recommendations to alleviate the potential hazard were made in the final report.

1.3 PREVIOUS REPORTS

The flood damage potential of the Bow River has been previously examined in several reports which have exposed the risk to developments in the flood plain and made suggestions as to the remedial works that might be undertaken to alleviate the risk. The principal reports are:

(1) Flood Plain of the Bow River in the City of Calgary, February 1968 by Montreal Engineering Company, Limited and commonly referred to as the 1968 Bow River Flood Plain Report.

(2) St. George's Island Flood Protection, February 1969 by Montreal Engineering Company, Limited.

(3) Bowness Flood Study, April 1971 by Montreal Engineering Company, Limited.

A brief synopsis of these reports is presented in the following paragraphs as much of the data used for this study have been taken from them.

131 BOW RIVER FLOOD PLAIN REPORT

This report comprising two volumes appraised the magnitude and frequency of flooding along the Bow River, commented upon the type of damage that is likely to occur and emphasized the need to manage developments in the flood plain. The extent of flooding was delineated for the following flows:

Above the confluence of the Elbow	Below the confluence of the Elbow
50,000 cfs	65,000 cfs
100,000 cfs	140,000 cfs

The following built-up areas were identified as being the most susceptible to flooding although no attempt was made to assess potential damages in quantitative terms:

- Bowness Area
- Westmount, Hillhurst and Sunnyside Area
- Downtown Area
- Pearce Estate-Inglewood Area including St. George's Island.

132 ST. GEORGE'S ISLAND FLOOD PROTECTION REPORT

This study was undertaken to determine the costs of protecting the island against summer flood flows of 50,000 cfs and 65,000 cfs upstream and downstream of the Elbow River respectively. The study evaluated dyking, landfill and channel improvements necessary to provide this protection without raising flood stages above the heights that would occur under present conditions.

While not specifically mentioned in the terms of reference, a discussion of winter ice flooding was included in the report. This type of flooding is generally more pertinent to the protection of the island as the stage rise caused by winter ice packing would exceed the stage rise of the 50,000/65,000 cfs summer flood, especially on the west side of the island.

In total, five schemes for alleviating flooding of the island were costed. Two schemes provided protection to the Park and Zoo areas only and three schemes provided protection to the Park, Zoo and campground area on the west side of the island.

The cost estimates of protection were based on surveyed cross-sections of the channel and flood plain which were carried out in late 1968. These sections have been used for this current study and modified where necessary for minor changes which have taken place in the interim period.

Consideration was also given to the effects of the passage of a catastrophic flood of 100,000/140,000 cfs. From this evolved a general concept for the ultimate form which rehabilitation of the channel should eventually take. This concept would allow for protection of the entire island from winter floods and major summer floods up to 50,000/65,000 cfs, and protection to the south bank flood plain from winter floods and summer floods up to 100,000/140,000 cfs. This ultimate concept of rehabilitation has been used as the basis for channel improvements and other works in the present studies.

133 BOWNESS FLOOD STUDY REPORT

The Bowness Flood Study evaluated in detail the flood damage potential along a 5 mile reach of the Bow River from Twin Bridges downstream to 37th Street N.W. and analyzed possible remedial measures. The detailed study of this reach of river was precipitated in the first instance by the extremely vulnerable location of some of the developments in the flood plain and by the danger of abnormal flood stages occasioned by possible rapid failure of a large active slide on a steep bank adjacent to the river below Crematorium Hill.

The study revealed that large-scale corrective measures involving major engineering works to alleviate the flood hazard along the reach could not be justified on economic grounds. The appropriate course of action was determined to be one comprising a mix of more modest engineering measures together with firm management of developments in the flood plain. The latter was deemed the key element in a strategy to minimize potential damages and hardships due to flooding along the study reach, and for that matter, throughout the City.

It was recognized that some of the measures tentatively recommended for the Bowness reach would benefit the whole of the Bow River flood plain in the City and not just the Bowness reach. Moreover, it was noted that some of the measures could not be applied to the Bowness reach in isolation, i.e. they should be integrated into a comprehensive plan of flood plain management and City development. For these reasons it was recommended that all parts of the City which are subject to the flood hazard should be examined in a similarly detailed manner. This is the prime function of this present study.

1.4 HYDROMETEOROLOGY

The drainage basin of the Bow River in Calgary has an area of 3,000 square miles at the gauging station at Langevin Bridge and an area of 3,930 square miles immediately above Fish Creek. Elevations in the basin range from about 3,400 feet at Calgary to 11,900 feet at the highest point of the Continental Divide to the west. The basin is divided topographically into two distinct areas by the front range of the Rockies.

Analyses of several of the more severe summer storms have been made by the Canadian Meteorological Service, and a review of these revealed that the storms causing summer floods in the Bow, although differing in detail, are characterized by heavy, intense rainfall occurring in a long narrow strip parallel to and east of the front range of the Rockies. Snowmelt alone does not cause flooding in Calgary, the maximum flow due to snowmelt being about 17,000 cfs.

The floods of 3 June 1929 and 3 June 1932 are the largest for which corresponding storm analyses have been made. These floods resulted from the storms ALTA-6-29 and ALTA-6-32 respectively, which exhibited the characteristics described. Several other essentially similar storms have occurred without producing a major flood in the Bow River, the storm ALTA-6-69 being a case in point. Comparing this storm with those of 1929 and 1932, it was found that the small "zone" of heaviest precipitation was located over the Bow Valley in 1929 and 1932, whereas in 1969 it was located over the headwaters of the Highwood and Oldman Rivers. This leads to the conclusion that it is only in these small zones that the rainfall is sufficient in amount and intensity to generate the high rates of runoff necessary for major floods. Much of the precipitation in summer is convective and it is believed that, in these small zones, convection is fully developed (cumulonimbus clouds).

The occurrence of this zone over a particular river basin may be the crucial factor in the formation of the larger floods, especially when prior soaking of the ground by low intensity rain has occurred. Since the area of these zones is relatively small in comparison with the area of the storm, it is to be expected that they will not occur over a particular river basin very frequently. There is reason to believe, however, that they occur somewhere along the front range of the Rockies in most years, and there is no reason why one should not recur at any time over the Bow Valley as in 1929 and 1932. It is believed that the major floods of 1879, 1897 and 1902 resulted from the occurrence of such zones but no storm analyses are available to confirm this.

1.5 HYDROLOGY

The hydrologic analyses undertaken during this study have been directed towards the establishment of the flood-frequency relationship of the Bow River upstream of the Elbow River. A summary of the analyses made is contained in the following sections and a more detailed account is presented in the Appendix.

Since there are virtually no records of floods in the reach of Bow River through Calgary downstream of the Elbow River, the flood-frequency relationship of this reach was based on data available for the Bow River at Calgary (upstream of the Elbow River) and the Elbow River at Glenmore Dam.

151 BOW RIVER UPSTREAM OF THE ELBOW RIVER

The data used in analyzing the flood-frequency relationship of this reach of Bow River are those pertaining to the gauging station at Langevin Bridge. The data are virtually the same as presented in the Bowness Flood Study.

As part of the Bowness Flood Study, several standard statistical methods were applied in analyzing the data, including the methods of Galton, Gumbel, Frechet and Slade. None of these provided a satisfactory fit to the flood-frequency data which exhibit a marked discontinuity in slope. A regional study of the flood-frequency relationships of other rivers in S.W. Alberta indicated that this discontinuity is not peculiar to the Bow River but is characteristic of all rivers draining the eastern slopes of the Rockies and having a part of their drainage area located west of the front range. In view of these findings, it was decided to "stick to the facts" as indicated by the data, and to adopt a graphically established flood-frequency relationship providing the best fit to the data. This led to the adoption of the following probabilities and return periods for the four projects as shown in Table 1-1.

TABLE 1-1

Flood-Frequency Relationship (Graphical Method)
Bow River Upstream of the Elbow River

Project Flood	Probability of Exceedance	Return Period
cfs	%	yrs
30,000	10.0	10
50,000	4.5	22
80,000	1.4	70
100,000	0.7	150

Further consideration has been given to this relationship following the concerns expressed at the Public Hearing on the Bowness Flood Study and the recent publication of a more suitable method of statistical analysis for flood-frequency relationships of this type.

It has been suggested that the discontinuity in slope of the indicated flood-frequency relationship may be due to any one, or a combination, of the following four possibilities:

1. The values of the large historical floods (those of 1879, 1897, and 1902) may be over-estimated causing them to plot high on the flood-frequency graph.

2. The flood sample may be biased by the chance occurrence within the 91-year period of record of one or several extremely rare floods.

3. The flood sample may not be composed of truly independent events.

4. The flood sample may not be homogeneous due to:

   a) a change in flood regime brought about by dam construction or major changes in forest cover.

   b) the occurrence of two types of floods, each type caused by a different flood-generating mechanism.

In view of the important practical implications of this study, it was considered imperative to discover which of these possible reasons was responsible for the discontinuity in slope of flood-frequency relationship and to adopt the most appropriate method of analysis available. An evaluation was made of each possibility, as described in full in the Appendix. It was concluded that:

1. The historical floods have been estimated with sufficient reliability to justify retaining them in the sample, and that the discontinuity in slope is not due to their inclusion. Samples from which the historical floods were successively rejected all show the same discontinuity, including a sample from which all historical floods were excluded.

2. The possibility that the sample contains extremely rare floods was rejected in view of the extremely low probabilities associated with the occurrence of such rare floods within a 91-year period. If the 80,000 cfs flood had a true average probability of exceedance of 1 in 1,000,000, as indicated by the trend of the lower floods, the probability that it would occur once in any 91-year period is only 1 in 90,000. The probability of it occurring twice, as it did, is even more remote.

3. The annual floods are independent events since they are separated by a prolonged season without floods and, thus, do not influence each other in any way.

4. A lack of homogeneity is evident; significance tests showed significant differences at the 5 per cent level in both the means and variances of flood samples corresponding to the periods of record before and after 1930.

5. The lack of homogeneity was not due to any change in flood regime, but to the operation of two different flood-generating mechanisms.

Between 1912 and 1955, reservoirs providing a total live storage of 318,000 cfs-days have been built, principally for power generation, in the Bow River Basin above Calgary. The possibility that the creation of this

storage could have brought about a significant change in the flood regime of the river is examined fully in the Appendix where the conclusion is reached that no significant change in the flood regime has resulted from this storage. This conclusion is based on the following considerations:

- the storage which can be effective for flood control of the Bow River at Calgary is a small proportion of the total live storage developed on the Bow River and is only a small proportion of the volume of water in a major flood.

- five of the six reservoirs, including the three with the largest live storages, are all located on tributaries of the Bow. These five contain 88 per cent of the total live storage but only control 28 per cent of the catchment area.

- the four largest reservoirs are all located west of the front range of the mountains upstream of the area where the flood-generating rainfall occurs, so that little of the flood runoff passes into them. Only Ghost and Barrier reservoirs are located east of the mountains in the area of greatest flood producing rainfall.

- calculations show that Ghost Reservoir reduced the 1932 flood in Calgary (53,600 cfs) by only a very small amount.

The possible influence of forest cover on flood runoff has also been investigated and is discussed in detail in the Appendix. Although forest cover changes can bring about significant changes in total runoff, their influence on rates of flood runoff is of little significance.

Two different flood-generating mechanisms appear to exist and these were identified tentatively as rainstorms in which cumulonimbus develops over the Bow River Basin, and those in which cumulonimbus develops instead over a neighbouring river basin. The non-occurrence of major floods in the Bow since 1932 is attributed to "persistence" of this situation since floods of similar intensity have occurred on neighbouring river basins within recent years. (Persistence means that the large (or small) members of a time series tend to occur in groups, possibly as a result of some cyclic variation in causative factors.)

During the course of this study, a recently published statistical method for analyzing a mixed sample of floods drawn from two different flood populations has been applied. This method is described in the Appendix and it provides a close fit to the sample data. The probabilities and return periods of the project flood are shown in Table 1-2.

Comparison of these results with those published previously in the Bowness Flood Study shows that the differences are not significant, and the results thus confirm those presented in the Bowness Flood Study.

TABLE 1-2

Flood-Frequency Relationship (Statistical Method)
Bow River Upstream of the Elbow River

Project Flood	Probability of Exceedance	Return Period
cfs	%	yrs
30,000	8.0	12.5
50,000	3.5	29
80,000	1.4	70
100,000	0.8	125

152 BOW RIVER DOWNSTREAM OF THE ELBOW RIVER

The sample of floods of the Elbow River covers the period from 1908 to 1969, and the flood-frequency relationship derived from it exhibits the same characteristics as that for the Bow River. The reasons for this are the same as for the Bow River and the same method of analysis was applied in establishing the flood-frequency relationship.

Having established flood-frequency relationships for the Bow upstream of the Elbow, and for the Elbow, a joint flood-frequency relationship for the Bow downstream of the Elbow may be derived assuming either that the floods of the Bow and Elbow occur completely independently or always simultaneously. A comparison of the recorded floods of the Bow and Elbow shows, however, that neither assumption is strictly valid. The floods of 1929 and 1932 on both rivers arrived almost simultaneously in Calgary indicating a high degree of dependence. A comparison of the smaller floods, however, shows that the annual flood in the Elbow often occurs on an entirely different occasion from that in the Bow, indicating that the smaller floods occur independently.

A flood sample for the Bow downstream of the Elbow was therefore made up by assuming that in any year the annual peak flow was the larger of the following:

- the sum of the annual peak flow in the Bow upstream of the Elbow and the concurrent daily mean discharge of the Elbow.
- the sum of the annual peak flow in the Elbow and the concurrent daily mean flow in the Bow upstream of the Elbow.
- the sum of the annual peak flows in the Bow and Elbow if they occurred on the same day or on consecutive days.

The resulting sample yielded on analysis a flood-frequency relationship similar in character to that of the Bow upstream of the Elbow, and the four project floods corresponding to those derived for the Bow upstream of the Elbow were as shown in Table 1-3.

TABLE 1-3

Flood-Frequency Relationship (Statistical Method)
Bow River Downstream of the Elbow River

Project Flood Upstream of the Elbow River	Project Flood Downstream of the Elbow River	Probability of Exceedance	Return Period
cfs	cfs	%	yrs
30,000	40,000	8.0	12.5
50,000	70,000	3.5	29
80,000	110,000	1.4	70
100,000	130,000	0.8	125

1.6 DELINEATION OF THE FLOOD PLAIN

In order to delineate as accurately as possible the extent of flooding through hydraulic computations, cross-sections of the Bow River channel and overbank areas were obtained in field surveys. The number of cross-sections and the dates of the surveys are shown in Table 1-4.

TABLE 1-4

Survey Data

Reach	Reach Length	No. of Cross-sections	Survey Date
	mi		
85th St. N.W. to 28th St. N.W.	6.3	22	May 1970
28th St. N.W. to Langevin Bridge	4.0	25	Aug 1971
Langevin Bridge to C & E Bridge	1.6	18	Nov 1968
C & E Bridge to Fish Creek	12.5	56	Aug 1971

From a review of recorded high water marks during past floods, inspection of aerial photographs and field reconnaissance, representative roughness coefficients were derived for the channel and overbank portions of the cross-sections. Using a comprehensive computer programme originally developed by the Hydrologic Engineering Centre (HEC) of the U.S. Army Corps of Engineers and adapted to suit available facilities and the needs of this study, backwater calculations were carried out to determine the water surface profiles at various flood flows. The programme computes the profiles associated with impediments to flow such as islands, bridges and levees, and also determines the effects of various changes in channel conditions. The calculated flood profiles along the Bow River are shown on Plates 1-2 to 1-6 inclusive.

By relating the profiles to specially prepared topographic maps with 2 feet contour intervals, the extent of flooding and depths of inundation on the flood plain were determined. With this information, the potential damages to existing developments in the flood plain were assessed as discussed in the following part of this report. The extent of the flood plain is roughly outlined on Plates 1-7 and 1-8.

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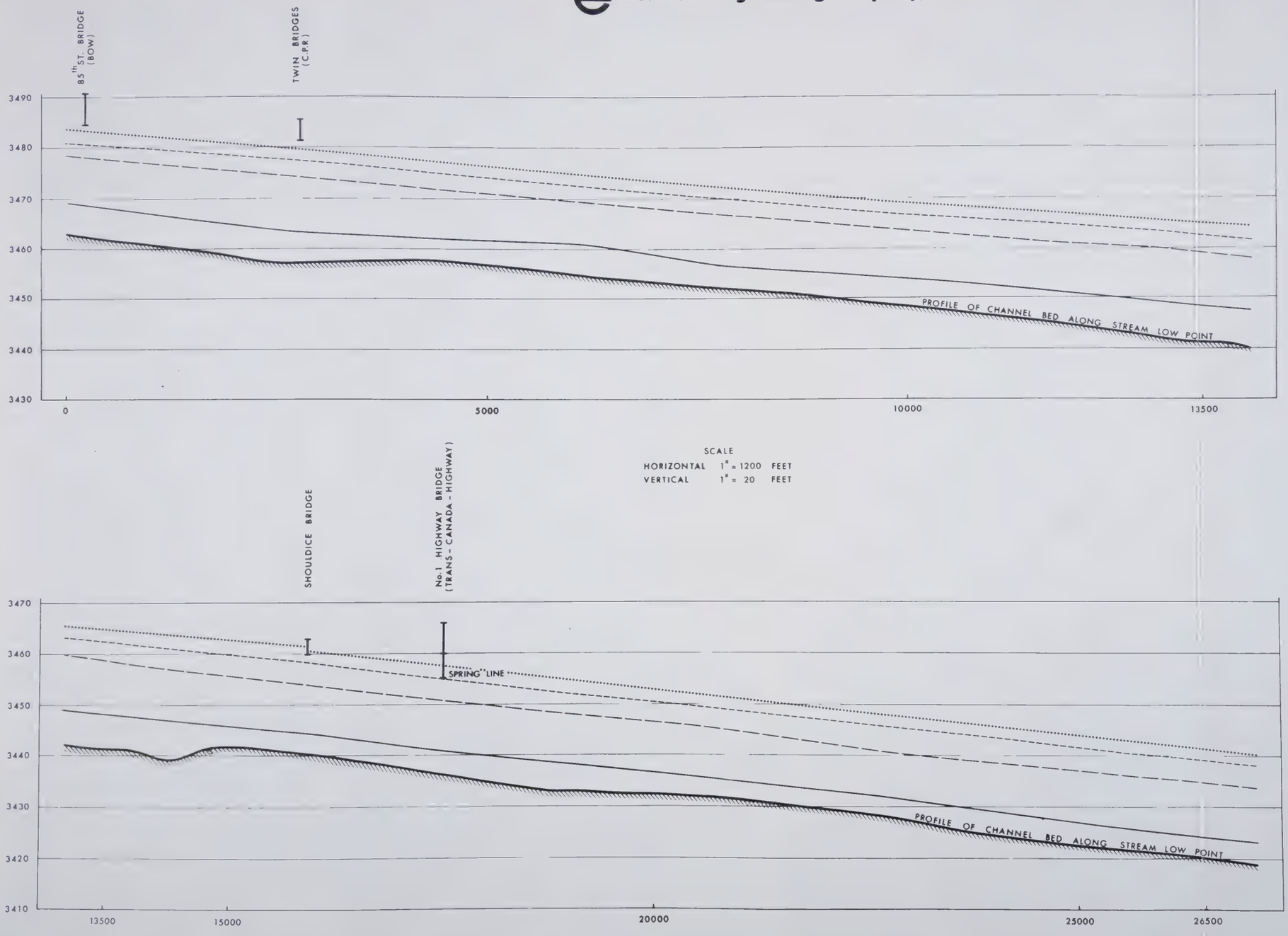

SCALE
HORIZONTAL 1" = 1200 FEET
VERTICAL 1" = 20 FEET

LEGEND:-

BRIDGE I — APPROXIMATE TOP OF ROAD ELEVATION
APPROXIMATE LOW CHORD ELEVATION

..... WATER SURFACE PROFILE AT 100,000 CFS

- - - - WATER SURFACE PROFILE AT 80,000 CFS

— — — WATER SURFACE PROFILE AT 50,000 CFS

——— WATER SURFACE PROFILE AT 3,300 CFS

NOTES:-

1 THE 3,300 CFS PROFILE OBTAINED FROM SURVEY READINGS

2 FLOOD PROFILES OBTAINED USING BACKWATER COMPUTATIONS ASSUMING IDEALIZED FLOW CONDITIONS

3 ELEVATIONS ARE REFERENCED TO THE CITY OF CALGARY DATUM, WHICH IS 35.56 FEET BELOW G.S.C. DATUM

PLATE 1-2

WATER SURFACE PROFILES AT SELECTED RIVER FLOWS 85 th ST. N.W. TO 45 th ST. N.W.

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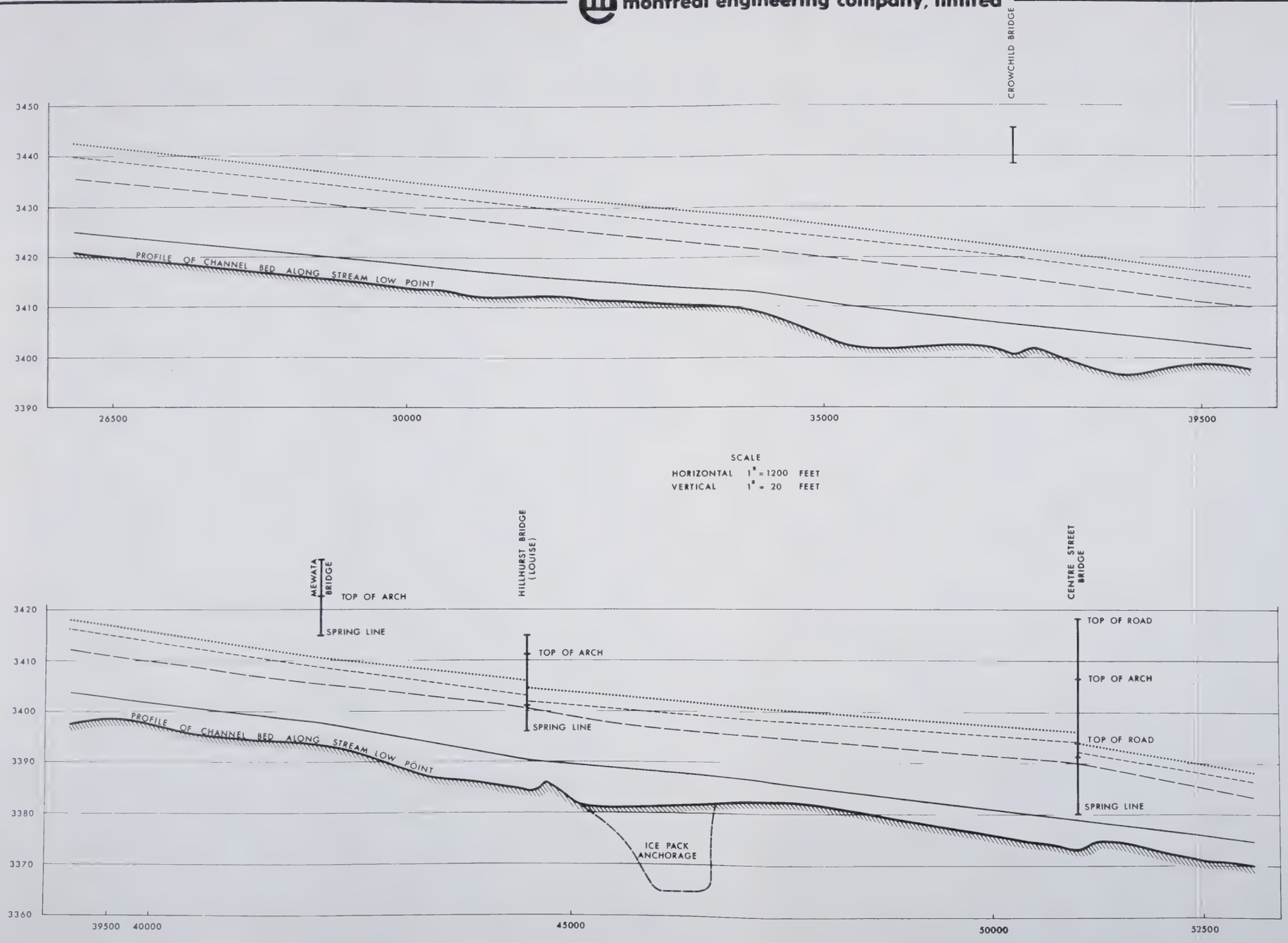


LEGEND:-

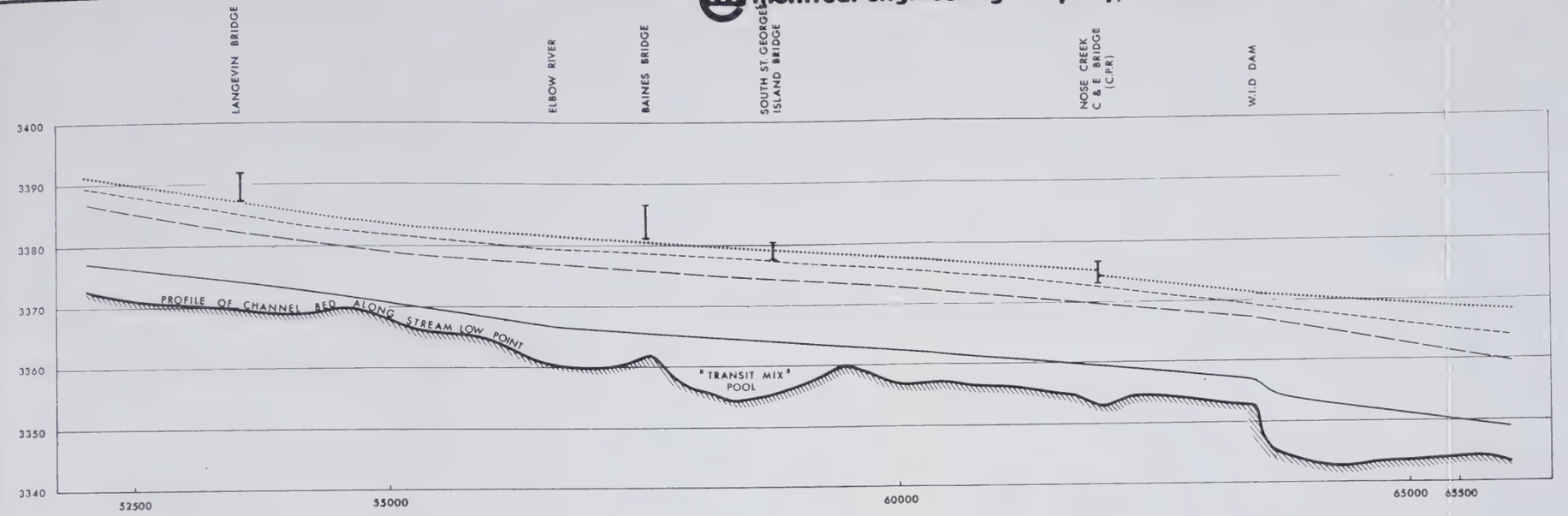
- BRIDGE I — APPROXIMATE TOP OF ROAD ELEVATION / APPROXIMATE LOW CHORD ELEVATION
- ..... WATER SURFACE PROFILE AT 100.000 CFS
- - - - - WATER SURFACE PROFILE AT 80.000 CFS
- — — — WATER SURFACE PROFILE AT 50.000 CFS
- ——— WATER SURFACE PROFILE AT 3.300 CFS

NOTES:-

1. THE 3,300 CFS PROFILE OBTAINED FROM SURVEY READINGS
2. FLOOD PROFILE OBTAINED USING BACKWATER COMPUTATIONS ASSUMING IDEALIZED FLOW CONDITIONS
3. ELEVATIONS ARE REFERENCED TO THE CITY OF CALGARY DATUM, WHICH IS 35.56 FEET BELOW G.S.C. DATUM

PLATE 1-3

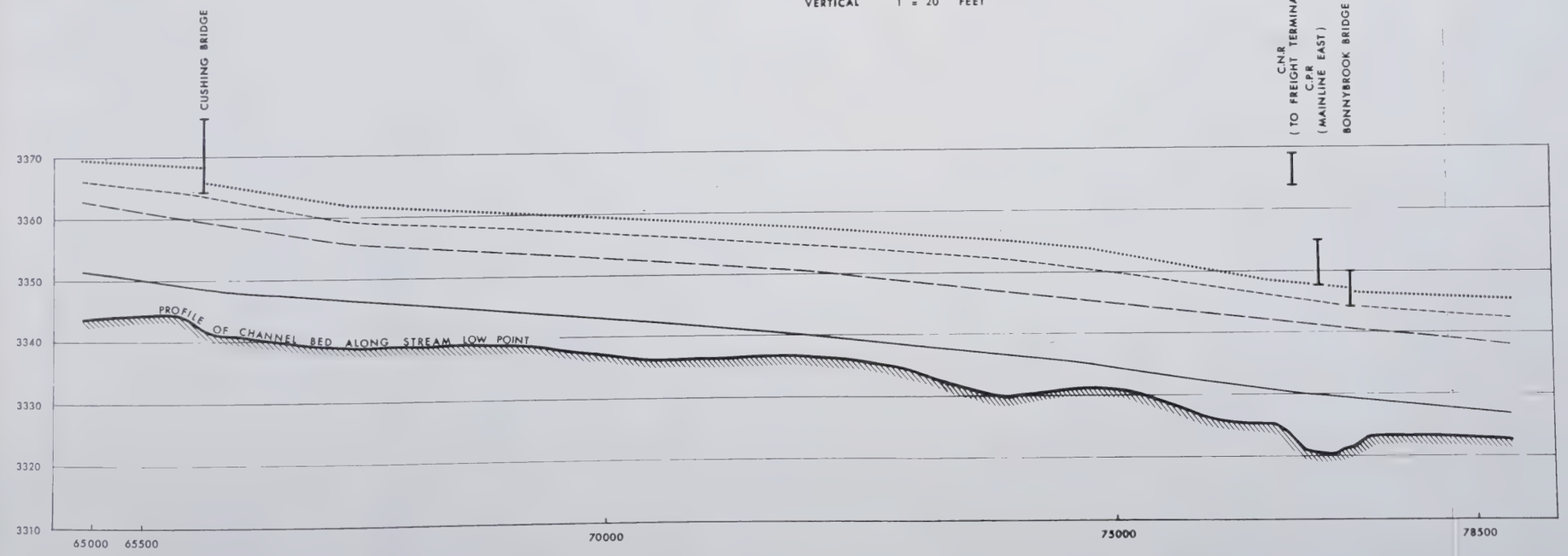
WATER SURFACE PROFILES
AT SELECTED RIVER FLOWS
45 th ST. N.W. TO 4 th ST. N.E.



LEGEND:-

- BRIDGE I — APPROXIMATE TOP OF ROAD ELEVATION / APPROXIMATE LOW CHORD ELEVATION
- ..... WATER SURFACE PROFILE AT 100,000 CFS ABOVE ELBOW & 130,000 CFS BELOW ELBOW
- - - - WATER SURFACE PROFILE AT 80,000 CFS ABOVE ELBOW & 110,000 CFS BELOW ELBOW
- — — WATER SURFACE PROFILE AT 50,000 CFS ABOVE ELBOW & 70,000 CFS BELOW ELBOW
- ——— WATER SURFACE PROFILE AT 3,300 CFS

SCALE
HORIZONTAL 1" = 1200 FEET
VERTICAL 1" = 20 FEET

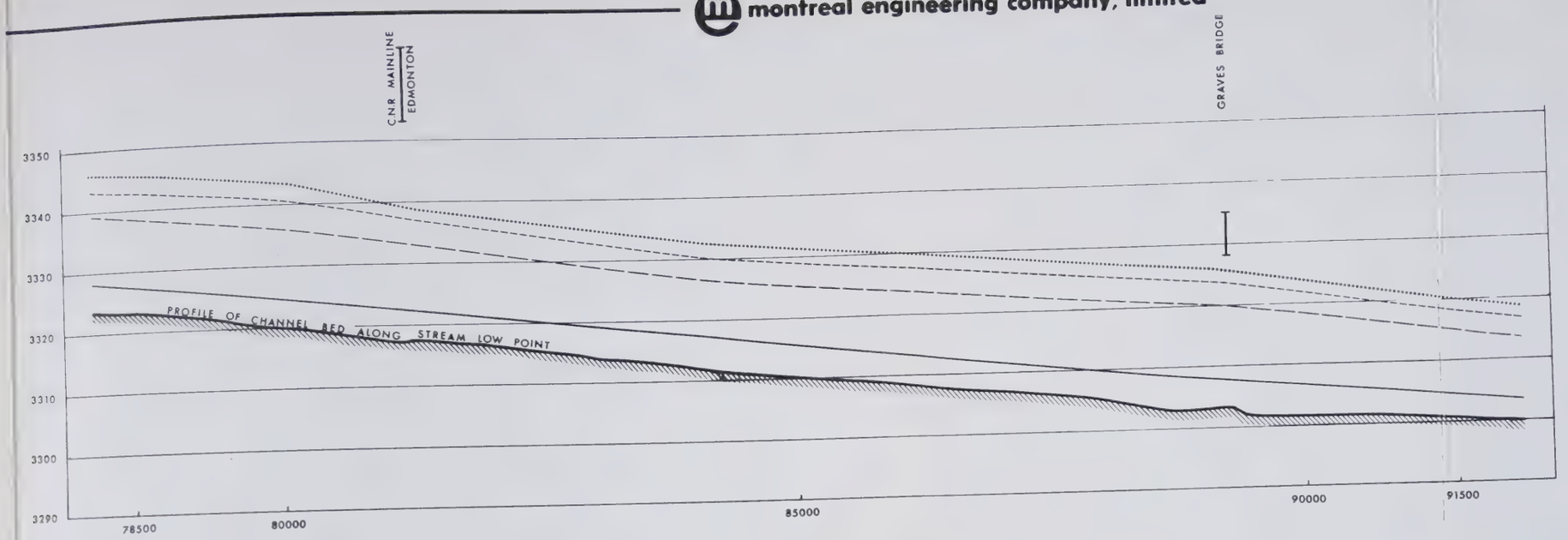


NOTES:-

1. THE 3,300 CFS PROFILE OBTAINED FROM SURVEY READINGS
2. FLOOD PROFILES OBTAINED USING BACKWATER COMPUTATIONS ASSUMING IDEALIZED FLOW CONDITIONS
3. ELEVATIONS ARE REFERENCED TO THE CITY OF CALGARY DATUM, WHICH IS 35.56 FEET BELOW G.S.C. DATUM

PLATE 1 - 4

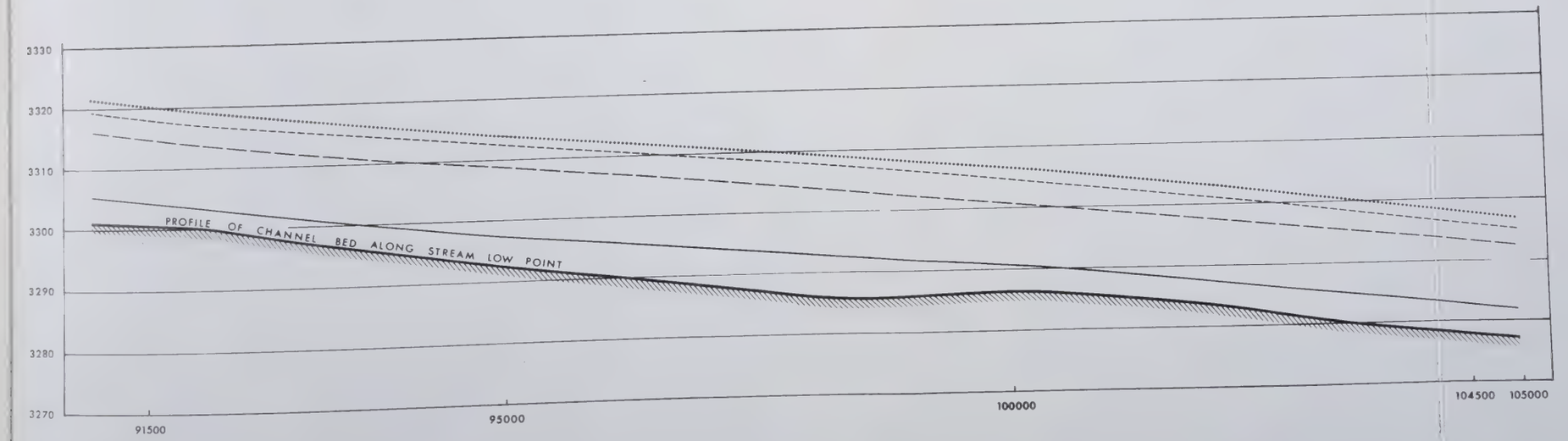
WATER SURFACE PROFILES
AT SELECTED RIVER FLOWS
4 th ST. N.E. TO 48 th AVE. S.E.



SCALE
HORIZONTAL 1" = 1200 FEET
VERTICAL 1" = 20 FEET

LEGEND:-

- BRIDGE I — APPROXIMATE TOP OF ROAD ELEVATION / APPROXIMATE LOW CHORD ELEVATION
- WATER SURFACE PROFILE AT 130,000 CFS
- WATER SURFACE PROFILE AT 110,000 CFS
- WATER SURFACE PROFILE AT 70,000 CFS
- WATER SURFACE PROFILE AT 3,300 CFS

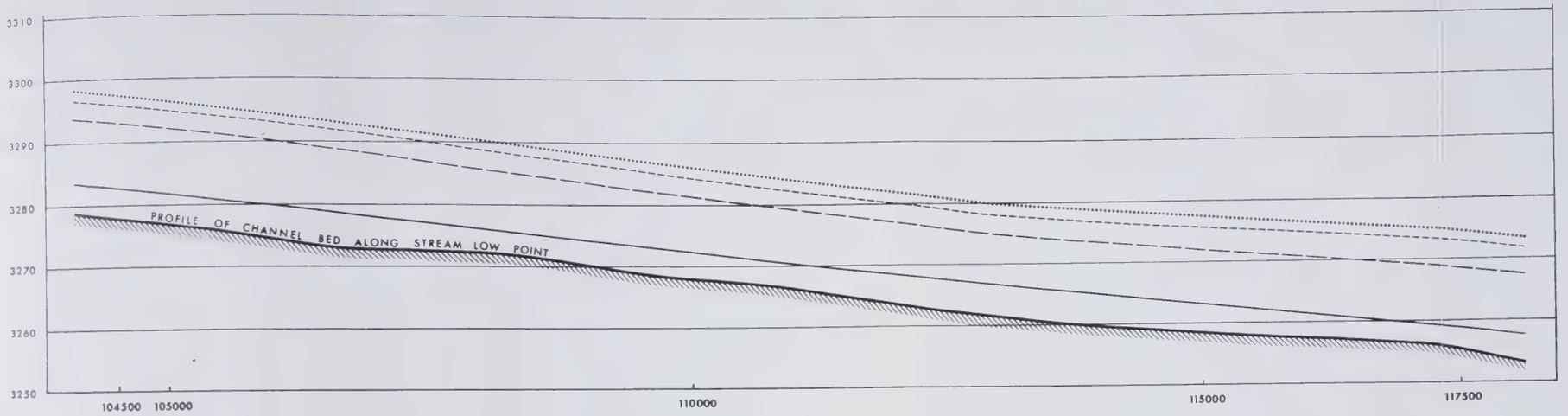


NOTES:-

1. THE 3,300 CFS. PROFILE OBTAINED FROM SURVEY READINGS
2. FLOOD PROFILES OBTAINED USING BACKWATER COMPUTATIONS ASSUMING IDEALIZED FLOW CONDITIONS
3. ELEVATIONS ARE REFERENCED TO THE CITY OF CALGARY DATUM, WHICH IS 35.56 FEET BELOW G.S.C. DATUM
4. EFFECT OF CONSOLIDATED CONCRETE'S AND GALLELLI'S PRIVATE BRIDGES NOT SHOWN SINCE THEY WOULD BE DESTROYED AT FLOWS LESS THAN 70,000 CFS

PLATE 1 - 5

WATER SURFACE PROFILES
AT SELECTED RIVER FLOWS
48th AVE. S.E. TO 110th AVE. S.E.



LEGEND:-

BRIDGE I — APPROXIMATE TOP OF ROAD ELEVATION
APPROXIMATE LOW CHORD ELEVATION

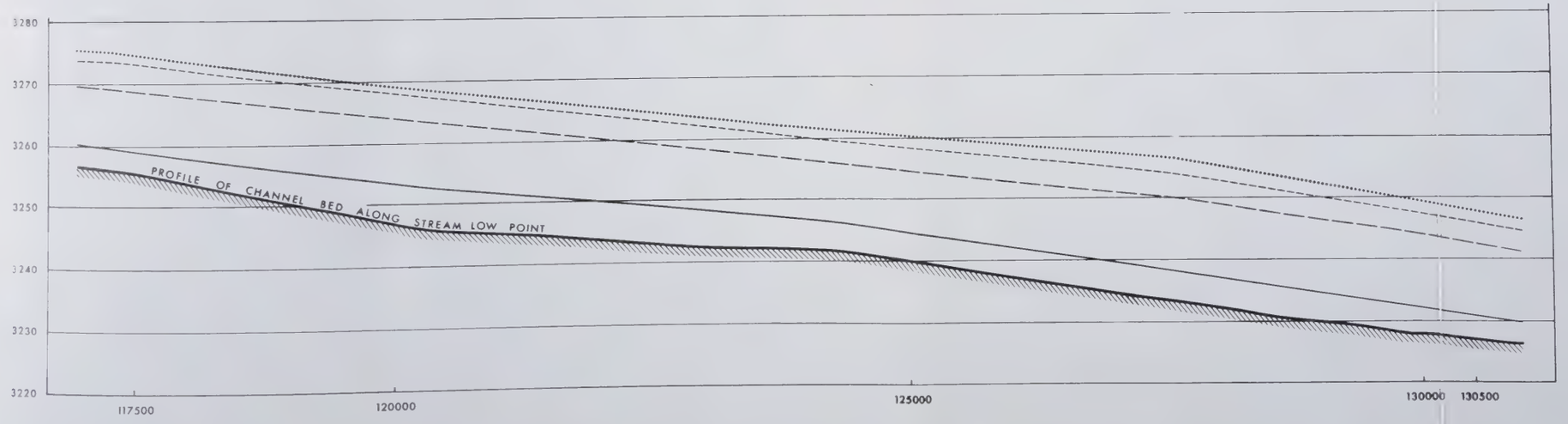
..... WATER SURFACE PROFILE AT 130,000 CFS

- - - - WATER SURFACE PROFILE AT 110,000 CFS

— — — WATER SURFACE PROFILE AT 70,000 CFS

——— WATER SURFACE PROFILE AT 3,300 CFS

SCALE
HORIZONTAL 1" = 1200 FEET
VERTICAL 1" = 20 FEET



NOTES:-

1 THE 3,300 CFS PROFILE OBTAINED FROM SURVEY READINGS

2 FLOOD PROFILES OBTAINED USING BACKWATER COMPUTATIONS ASSUMING IDEALIZED FLOW CONDITIONS

3 ELEVATIONS ARE REFERENCED TO THE CITY OF CALGARY DATUM, WHICH IS 35.56 FEET BELOW G.S.C. DATUM

PLATE 1-6

WATER SURFACE PROFILES
AT SELECTED RIVER FLOWS
110 th AVE. S.E. TO FISH CREEK

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LIST OF BRIDGES – ▽

1 85th ST. N.W.
2 TWIN BRIDGES (C.P.R MAINLINE WEST)
3 SHOULDICE
4 TRANS – CANADA HIGHWAY
5 CROWCHILD
6 MEWATA (14th ST. W.)
7 LOUISE (HILLHURST)
8 PEDESTRIAN
9 CENTRE STREET
10 LANGEVIN
10a NEW LANGEVIN
11 BAINES
12 SOUTH ST. GEORGE'S IS.
13 PEDESTRIAN
14 C. & E. (C.P.R MAINLINE EDMONTON)
15 CUSHING
16 C.N.R – FREIGHT TERMINAL
17 C.P.R – MAINLINE EAST
18 BONNYBROOK
19 C.N.R – MAINLINE EDMONTON

LEGEND

RIVER CHANNEL

FLOOD PLAIN FOR 80,000 cfs. ABOVE ELBOW
110,000 cfs. BELOW ELBOW

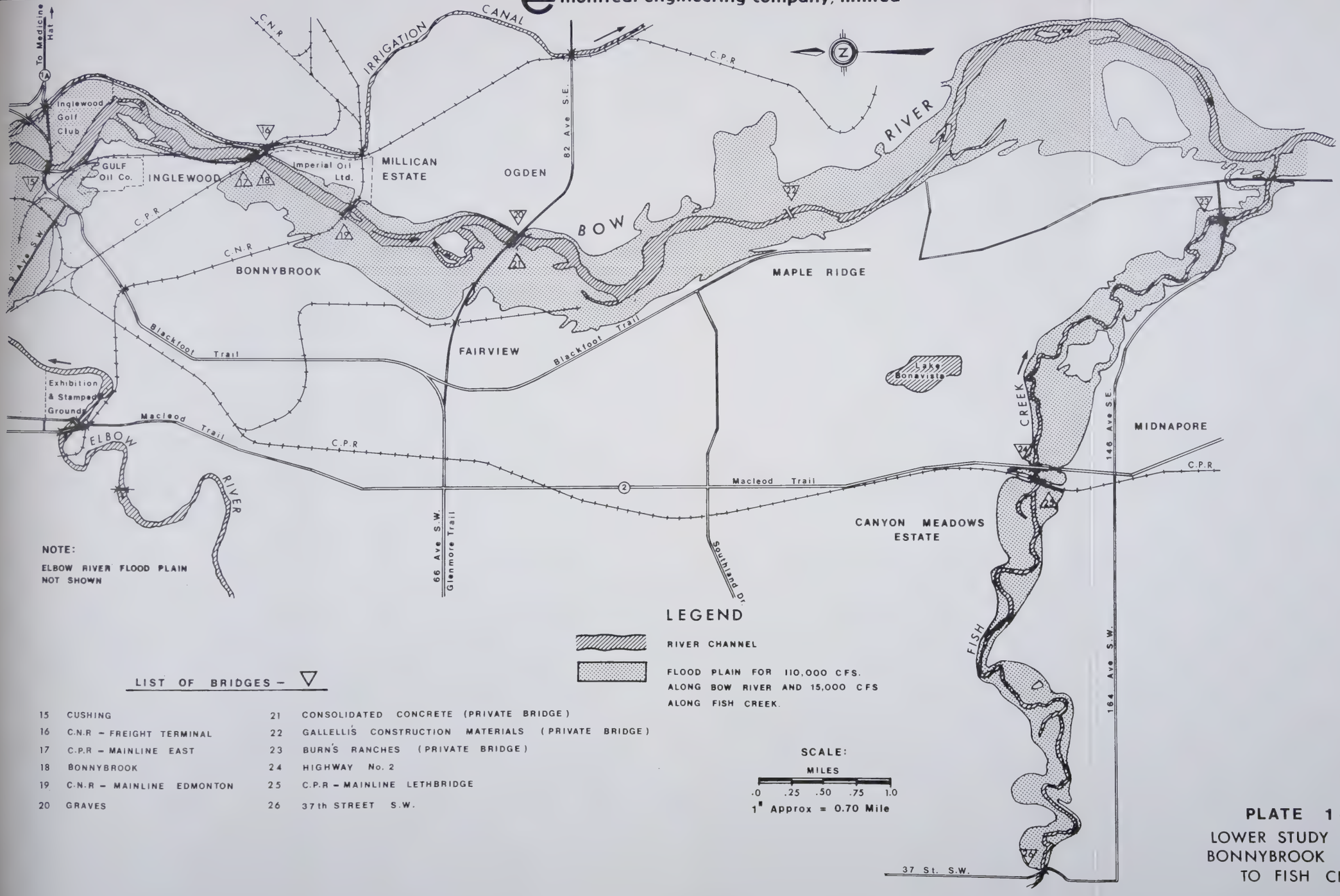
SCALE:

MILES
.0 .25 .50 .75 1.0

1" Approx = 0.70 Mile

PLATE 1 – 7

UPPER STUDY REACH
85 th ST. BRIDGE
TO BONNYBROOK BRIDGE



NOTE:
ELBOW RIVER FLOOD PLAIN NOT SHOWN

LEGEND

RIVER CHANNEL

FLOOD PLAIN FOR 110,000 CFS. ALONG BOW RIVER AND 15,000 CFS ALONG FISH CREEK.

LIST OF BRIDGES – ▽

15	CUSHING	21	CONSOLIDATED CONCRETE (PRIVATE BRIDGE)
16	C.N.R – FREIGHT TERMINAL	22	GALLELLIS CONSTRUCTION MATERIALS (PRIVATE BRIDGE)
17	C.P.R – MAINLINE EAST	23	BURN'S RANCHES (PRIVATE BRIDGE)
18	BONNYBROOK	24	HIGHWAY No. 2
19	C.N.R – MAINLINE EDMONTON	25	C.P.R – MAINLINE LETHBRIDGE
20	GRAVES	26	37th STREET S.W.

SCALE:
MILES
.0 .25 .50 .75 1.0
1" Approx = 0.70 Mile

PLATE 1-8
LOWER STUDY REACH
BONNYBROOK BRIDGE
TO FISH CREEK

PART 2 - POTENTIAL DAMAGES

CONTENTS

		PAGE
2.1	METHODOLOGY	2-1
211	STAGE-DAMAGE RELATIONSHIPS	2-1
212	GENERAL CRITERIA	2-2
213	CATEGORIES OF DAMAGE	2-3
2.2	AREAS AFFECTED	2-3
221	BOWNESS	2-4
222	WESTMOUNT, HILLHURST AND SUNNYSIDE	2-5
223	DOWNTOWN	2-7
224	BRIDGELAND	2-9
225	INGLEWOOD, PEARCE ESTATE, BONNYBROOK	2-10
226	OTHER AREAS	2-12
227	BRIDGES	2-12
2.3	AVERAGE ANNUAL FLOOD DAMAGES	2-14

TABLES

TABLE		
2-1	Distribution of Houses in the Bowness Flood Plain	2-4
2-2	Potential Flood Damage in the Bowness Area	2-5
2-3	Distribution of Properties in the Westmount, Hillhurst, Sunnyside Flood Plain	2-6
2-4	Potential Flood Damage in the Westmount, Hillhurst, Sunnyside Area	2-7
2-5	Distribution of Properties in the Downtown Flood Plain	2-8

PAGE

TABLE

2-6 Potential Flood Damage in the Downtown Area 2-8

2-7 Distribution of Properties in the Bridgeland Flood Plain 2-9

2-8 Potential Flood Damage in the Bridgeland Area 2-10

2-9 Distribution of Properties in the Inglewood, Pearce Estate, Bonnybrook Flood Plain 2-11

2-10 Potential Flood Damage in the Inglewood, Pearce Estate, Bonnybrook Area 2-11

2-11 Potential Flood Damage to Bridges 2-13

2-12 Distribution of Properties in the Bow River Flood Plain 2-14

2-13 Potential Flood Damages along the Bow River 2-14

FIGURES

FIGURE

2-1 Annual Flood Damage throughout the City of Calgary 2-16

The probable extent of flooding and the depths of inundation on the flood plain throughout the City were determined by relating computed flood profiles to specially prepared topographic maps. The profiles were calculated for idealized flow conditions assuming that no extraordinary high water levels from blocked bridges or from the massive failure of river banks would occur. Thus, the actual flow profiles may be slightly higher than the computed profiles along some reaches and hence the potential damages presented in this part of the report are likely to be underestimated on this account.

The potential damages are estimated for summer rainfall floods only as the existing protective works have minimized the risk of winter inundation from ice packing. This risk is now believed to be remote in winter along the Bowness reach as a result of the construction of Bearspaw Dam. Flooding due to winter ice packing is still, however, a possibility in other areas downstream but, as a result of protective works undertaken in the 1950's, the hazard is one of modest proportions compared to the hazard of a major summer flooding. In estimating the damages, it has been assumed that if the winter flood protective works are destroyed by major summer floods, (as will partially be the case due to the erosion of unprotected dykes and the infilling of the Ice Pack Anchorage), the reconstruction of these works will be a first priority. Thus, the estimates derived for average annual damages in this part of the report do not include any allowance for damages that might be caused from inundation due to winter ice packing.

2.1 METHODOLOGY

Having determined frequency-discharge relationships through hydrologic analysis and stage-discharge relationships through hydraulic calculations, the next step in the derivation of potential damages was the construction of stage-damage relationships. In order to derive these relationships, a field survey of most buildings in the flood plain was carried out to determine the type and use of the buildings and their elevations relative to calculated flood profiles.

211 STAGE-DAMAGE RELATIONSHIPS

Stage-damage curves for individual structures derived as a result of detailed surveys in Southern Ontario in 1968 have been used as the basis for calculating potential damages. These curves have been adjusted and up-dated to suit prevailing conditions in Calgary through information obtained from a local building contractor and by reference to consumer price indices.

The majority of the structures in the flood plain are detached, single-family dwellings and in order to assess the damages to the diversity of dwellings which are encountered, a classification system similar to that used in Ontario was adopted as follows:

Class A - Good quality construction, large to medium size, architecturally designed structures. Many of the houses falling into this category are the newer brick houses.

Class B - Average quality, medium-size, mass produced or individually built structures. The majority of houses fall into this category with most of these having wooden exteriors.

Class C - Poor quality, medium to small size, individually built structures with wooden or stucco exteriors. Today, these houses probably would not meet the minimum requirements of the City building codes.

A correlation was established between the classification system and the assessed building value of a residence as determined from City of Calgary valuation lists. Thus, all single-family dwellings in the flood plain were categorized. Potential flood damage to these dwellings was then calculated from stage-damage curves applicable to the contents and structure of each class of dwelling.

Stage-damage curves based on the area of the building involved were also derived for the contents and structure of the following commercial properties; grocery, furniture, shoe, drug, men's wear and ladies' wear stores. Damages to commercial and industrial properties not falling into these categories were evaluated using a combination of curves or by direct visits to the owners or managers of such properties.

212 GENERAL CRITERIA

In calculating potential flood damages, account has only been taken of properties affected by overland flow. Many other properties outside the project flood plains would also experience damage but this would be confined to basements and be caused by sewer back-up and/or seepage. This form of damage is usually small in comparison to the damage caused by overland flow.

Other criteria adopted in assessing the damages were as follows:

- Indirect damages such as cost of alternative accommodation during the flood, extra food costs, wages lost and flood fighting were calculated as 15 per cent of the direct damage.

- No buildings in the flood plain would be subject to flow velocities greater than 4 feet per sec., velocities which would be capable of sweeping buildings off their foundations. However, it is assumed that where depths of water on residential structures exceed 4 feet above the first floor level, ten per cent of the structures in this category would be totally destroyed as a result of the force exerted by the depth of flowing water.

- Clean-up costs for removing sediment deposited during the flood would not be significant in comparison to the direct damages.

- Buildings would not be subjected to head differences great enough to cause structural failure.

213 CATEGORIES OF DAMAGE

In the following sections of this report which derive in detail the potential flood damages in specific areas of the flood plain, three main categories of damage are itemized in order to indicate the relative impact of flooding. These categories are as follows:

- Residential

- Commercial and Industrial

- Public Property.

Residential damages are divided into two components; one for single-family and two-family dwellings, and the other for apartment (multi-family) dwellings and nursing homes.

Commercial and industrial damages include damages to stores, banks, cinemas, gas-stations, manufacturers and other similar establishments.

Public property damages include but are not limited to damages to schools, churches, fire stations, public and private transportational and communicational facilities, and existing flood protective works. These damages include also the clean-up costs necessary to remove sediment and debris from pavements and sidewalks. Substantial structural failure of public property, such as settlements and washouts of pavements and sidewalks, is not anticipated to be a major factor in the damage estimates as, for floods up to 100,000/130,000 cfs, the average velocity of flow across most of the developed areas of the flood plain will be less than 3 feet per second.

Other important categories of damage are those to bridges and to the river channel. Both will result in the main from the erosive potential of the river at flood flows. Whereas an approximate estimate of the damages to bridges is possible, channel damage can be discussed in qualitative terms only. At flows in excess of 50,000 cfs, it is anticipated that several properties fronting the river may be cut back especially where bars and islands direct the flow into the banks. The extent of this damage is indeterminate but would necessitate a major programme of river channel rehabilitation after the passage of the flood.

2.2 AREAS AFFECTED

The following paragraphs deal with the potential flood damages on a district by district basis, working downstream from Bowness. By dealing with the damages in this way, it is possible to draw conclusions as to the relative importance of the flood hazard in the various parts of the City.

221 BOWNESS

The potential flood damage estimates derived from this area apply to flood plain lands from 85th Street Bridge to 37th Street N.W. The majority of the damage potential along this reach of the river will be to the residential area on the south bank between Twin Bridges and Shouldice Bridge. Most of the buildings in the flood plain, especially in the higher risk areas closest to the river, are single-family, wood-frame structures founded on poured concrete or concrete block basements. The class distribution of private residences within the various project flood plains is shown in Table 2-1.

TABLE 2-1

Distribution of Houses in the Bowness Flood Plain

Project Flood	Number of Houses			
	Class A	Class B	Class C	Total
cfs				
50,000	15	76	23	114
80,000	28	179	84	291
100,000	36	199	90	325

There are few commercial structures in the flood plain and the only buildings other than residences which will experience significant damage from the project floods are a telephone exchange and a mobile-home park. One of the most vulnerably situated of the residences is Bow View Nursing Home on Montgomery Boulevard. Estimates of damage to the mobile-home park have not been made as it has been recommended that it be moved to a more suitable location at an early date because of its extreme vulnerability.

Flooding of developed property in the area will commence at flows of the order of 30,000 cfs. Table 2-2 itemizes the potential flood damages in the Bowness area resulting from the project floods.

TABLE 2-2

Potential Flood Damage in the Bowness Area

Item	Project Flood 50,000 cfs	80,000 cfs	100,000 cfs
	$'000	$'000	$'000
Private Residences			
- Single and two family	130	510	730
- Multiple family	88	110	110
Commercial/Industrial	-	-	-
Public Property	60	145	180
Total (Structure & Contents)	278	765	1,020
Indirect Damage @ 15%	42	115	150
Total	320	880	1,170

222 WESTMOUNT, HILLHURST AND SUNNYSIDE

Along the 4 mile reach of river from 37th Street N.W. to Centre Street Bridge, the majority of the flood damage would occur in the low-lying areas of Westmount, Hillhurst and Sunnyside on the north bank. At catastrophic flows, some damage would also occur to a few properties in Parkdale adjacent to 37th Street N.W. and to several properties on the south bank of the river in the downtown area opposite Prince's Island. Potential damages to properties in the downtown area between Louise Bridge and Centre Street Bridge are dealt with in the following section.

The major portion of the flood plain in Westmount, Hillhurst and Sunnyside is designated as a General Residential District which has been intensively developed with few open spaces, the most notable being Prince's Island, Riley Park on the outer edge of the flood plain and the strip of land between Memorial Drive and the top of the river bank. The specified uses in the district include one-family and two-family dwellings, and apartment houses. At the present time, most residences are single-family, wood-frame structures although many of these structures have been replaced in recent years by 3 or 4-storey apartment houses with basement living quarters. There appears to be a trend towards these multiple-family dwellings.

The area is serviced by a mix of commercial enterprises which are located in the main in the General Commercial Districts along 10th Street N.W. and 14th Street N.W. Outside these districts, the principal structures other than private residences are the CBC Building on Memorial Drive, the Calgary School Board Stores Workshop on 9th Street N.W., schools, churches and two fire stations. The distribution of properties within the flood plains of the various project floods is shown in Table 2-3.

TABLE 2-3

Distribution of Properties in the Westmount, Hillhurst, Sunnyside Flood Plain

Project Flood	Houses Class A	Houses Class B	Houses Class C	Total Houses	Apartment Blocks	Commercial/ Industrial
cfs						
50,000	1	144	10	155	1	2
80,000	11	1,047	108	1,166	68	91
100,000	15	1,335	138	1,488	74	116

Flooding of developed property in the area will commence at flows in the order of 25,000 cfs on the eastern side of Sunnyside at 3 to 4th Streets N.W. Table 2-4 itemizes the potential damages to the area resulting from the project floods. The damage to public property includes an allowance for the loss of the Ice Pack Anchorage which will be filled at flood flows of 50,000 cfs (or less) and for the loss of part of the existing dyke protection.

the pace of redevelopment and possibly bring about a substantial reduction in the number of single-family dwellings in the area. The distribution of properties within the various project flood plains is shown in Table 2-5.

TABLE 2-5

Distribution of Properties in the Downtown Flood Plain

Project Flood	Houses Class A	Houses Class B	Houses Class C	Total Houses	Apartment Blocks	Commercial/ Industrial
cfs						
50,000	-	-	-	-	-	-
80,000	4	304	31	339	12	106
100,000	4	338	31	373	13	131

Flooding of property in the area will commence at overbank flows in the order of 60,000 cfs in the vicinity of Centre Street Bridge although some flooding through the backing up of storm sewers will occur ahead of this. Table 2-6 itemizes the potential flood damages in the area resulting from the project floods.

TABLE 2-6

Potential Flood Damage in the Downtown Area

Item	Project Flood 50,000 cfs	80,000 cfs	100,000 cfs
	$'000	$'000	$'000
Private Residences			
- Single and two family	-	200	300
- Multiple family	-	40	40
Commercial/Industrial	-	980	1,650
Public Property	-	120	150
Total (Structure & Contents)	-	1,340	2,140
Indirect Damage @ 15%	-	200	320
Total	-	1,540	2,460

224 BRIDGELAND

On the north bank of the river from Centre Street to the C & E Bridge, the flood plain encompasses a modest amount of relatively intensively developed land from approximately Langevin Bridge downstream to 12th Street N.E. The developed land is generally designated as a Two-Family and General Residential District with part of the vicinity of Langevin Bridge designated as a General Commercial District and part as a Direct Control District.

Most of the buildings in the flood plain are older vintage structures and a few of these are being removed in conjunction with the road works for the new Langevin Bridge. One new building of note in the area is a multi-storey public housing project on Memorial Drive between 6A and 7A Streets. This building is elevated on columns above anticipated flood levels.

On the east side of the area and fronting Memorial Drive are two developments - a senior citizens' housing project and residences attached to the Canadian National Institute for the Blind - where the hardship factor from flooding could be especially severe. However, both are in a fairly low risk area where flooding will not be experienced until the flow is in the order of 80,000/110,000 cfs.

The potential flood damages to the St. George's Island Zoo, which is part of this area, have not been estimated and the number of buildings on the island is not reflected in Table 2-7 which shows the distribution of properties in the flood plain. Redevelopment of part of the zoo is currently being planned and the amount of damage will depend in great measure on the extent to which the flood hazard to the island is acknowledged. Despite its high risk, the potential damages to the zoo itself are unlikely to represent a significant portion of the overall damage potential through the City.

TABLE 2-7

Distribution of Properties in the Bridgeland Flood Plain

Project Flood	Houses			Total Houses	Apartment Blocks	Commercial/ Industrial
	Class A	Class B	Class C			
cfs						
50,000/70,000	-	-	-	-	-	-
80,000/110,000	1	115	4	120	1	15
100,000/130,000	1	128	7	136	1	15

Flooding of St. George's Island will commence at flows in the order of 30,000/40,000 cfs and flooding of property on the north bank proper will commence at flows in the order of 70,000/95,000 cfs. Table 2-8 itemizes the potential damages in the area resulting from the project floods.

TABLE 2-8

Potential Flood Damage in the Bridgeland Area

Item	Project Flood 50,000 cfs	80,000 cfs	100,000 cfs
	$'000	$'000	$'000
Private Residences			
- Single and two family	-	160	370
- Multiple family	-	60	60
Commercial/Industrial	-	110	180
Public Property	-	50	80
Total (Structure & Contents)	-	380	690
Indirect Damage @ 15%	-	60	110
Total	-	440	800

225 INGLEWOOD, PEARCE ESTATE, BONNYBROOK

This area includes the relatively developed flood plain on the right bank of the river from the Elbow River downstream to the Bonnybrook Bridges and the generally open space left bank flood plain from the C & E Bridge to Bonnybrook Bridges. This left bank flood plain encompasses the Inglewood Golf Club and the land associated with the WID Canal, the most significant development being the mobile-home park at the junction of the Blackfoot Trail and Highway No. 1A. Potential flood damage to the park has not been assessed as this park may be relocated in conjunction with the proposed extensions to the Blackfoot Trail.

The right bank flood plain above the C & E Bridge is designated in the main as a Two Family Residential District, this district flanking either side of a Light Industrial District running along 9th Avenue S.E. Immediately upstream of the bridge and adjacent to the river, the low-lying land which

accommodates a cement block and a precast concrete manufacturing operation is designated as a Heavy Industrial District. The right bank flood plain downstream, where the principal developments are single-family dwellings, comprises a mix of designated uses. Open spaces along this reach of river include the Pearce Estate and the Inglewood Bird Sanctuary.

Table 2-9 shows the distribution of properties in the various project flood plains and includes some industrial buildings in a relatively low risk part of the right bank flood plain immediately downstream of Bonnybrook Bridge.

TABLE 2-9

Distribution of Properties in the Inglewood, Pearce Estate, Bonnybrook Flood Plain

Project Flood	Houses Class A	Houses Class B	Houses Class C	Total Houses	Apartment Blocks	Commercial/ Industrial
cfs						
70,000	-	134	4	138	1	16
110,000	-	491	31	522	2	130
130,000	-	500	35	535	2	143

Flooding to developed property will commence upstream of the C & E Bridge at flows in the order of 40,000 cfs. Table 2-10 itemizes the potential flood damages in the area resulting from the project floods.

TABLE 2-10

Potential Flood Damage in the Inglewood, Pearce Estate, Bonnybrook Area

Item	Project Flood 70,000 cfs	110,000 cfs	130,000 cfs
	$'000	$'000	$'000
Private Residences			
- Single and two family	155	1,000	1,490
- Multiple family	5	25	110
Commercial/Industrial	150	895	1,800
Public Property	40	80	300
Total (Structure & Contents)	350	2,000	3,700
Indirect Damage @ 15%	50	300	560
Total	400	2,300	4,260

226 OTHER AREAS

From Bonnybrook Bridge downstream to Fish Creek, the flood plain occupies a substantial portion of undeveloped land, most of which lies on the right (west) bank of the river. The land along this reach is principally designated as a Direct Control District or as an Agricultural (Future Industrial) District.

The major developments in the flood plain are two sand and gravel processing operations with concrete batching plants. Both operations are adjacent to the river and close to the site of worked-out gravel pits, and both are extremely vulnerable to flooding. At the present time, there is no mining for gravel in the flood plain and material for processing is trucked into both operations.

Other flood damage along the reach will be experienced to the Bonnybrook and Ogden sewage treatment plants which will probably be temporarily out of service at flows in excess of 110,000 cfs. In addition, some losses to utilities with support structures in the high risk areas of the flood damage downstream of Bonnybrook Bridge is likely to be modest in relation to that upstream. Consequently, in the summary of damages presented in "2.3 Average Annual Flood Damages", nominal amounts only have been allowed for this damage.

227 BRIDGES

The estimates of potential damages to bridges are presented in Table 2-11. Most bridge failures under flood conditions are caused by erosion and scour of abutments and piers and an accurate, quantitative assessment of such factors is impossible. Thus, the estimate of potential damages to bridges is in large measure a matter of judgement and should only be considered as an order of magnitude appraisal.

The present values assigned to bridges and shown in the table are generally based on the following replacement costs:

Road bridges	$30 per sq. ft. of deck
Railway bridges	$1,400 per lin. ft.

The replacement cost is depreciated on a straight line basis over the anticipated life of the bridge in order to determine its present value. In the event that a bridge would be totally destroyed, the damage is estimated at its present value.

In the event of a flood in the order of 80,000/110,000 cfs, it should be noted that only three road crossings of the river will remain in operation. These are 85th Street N.W., Trans-Canada Highway and Crowchild Bridges.

TABLE 2-11

Potential Flood Damage to Bridges

	Bridge	Date of Construction	Span	Use	Estimated Present Value	50,000/ 70,000 cfs	80,000/ 110,000 cfs	100,000/ 130,000 cfs
			ft.		$'000	$'000	$'000	$'000
1.	85th Street N.W.	1961	430	2 Lanes	420	-	50	100
2.	Twin Bridges (CPR Mainline West)	1929	215+290	1 Track	130	-	-	130
3.	Shouldice	1909	390	2 Lanes	80	-	20	40
4.	Trans-Canada Highway	1958	550	4 Lanes	890	-	-	-
5.	Crowchild	1967	520	6 Lanes	1,330	-	30	50
6.	Mewata	1954	500	5 Lanes	920	-	-	30
7.	Louise (Hillhurst)	1920	565	4 Lanes	350	-	30	50
8.	Prince's Island	1968	120	Pedestrian	40	-	-	-
9.	Centre Street	1916	450	4 Lanes	230	-	50	50
10.	Langevin	1910	380	3 Lanes	120	-	-	120
11.	New Langevin	1972	820	4 lanes	1,600	-	-	-
12.	Baines	1964	260	2 Lanes	270	-	50	100
13.	South St. George's Island	1908	360	2 Lanes	70	70	70	70
14.	St. George's Island	1955	200	Pedestrian	20	20	20	20
15.	C & E (CPR Mainline Edmonton)	1902	610	1 Track	120	-	120	120
16.	Cushing	1956, 1965	430	4 Lanes	1,000	-	50	850
17.	CNR Freight Terminal at Bonnybrook	1912	450	1 Track	170	-	50	50
18.	CPR Mainline East at Bonnybrook	1911	465	3 Tracks	230	-	-	-
19.	Bonnybrook	1912	455	2 Lanes	140	-	-	30
20.	CNR Mainline Edmonton	1915	540	1 Track	200	-	30	50
21.	Graves (Glenmore Trail)	1970	680	4 Lanes	1,400	-	-	-
22.	Consolidated Concrete (Private)		330	1 Lane	40	40	40	40
23.	Gallelli Construction (Private)		300	1 Lane	40	40	40	40
					9,810	170	650	1,940

2.3 AVERAGE ANNUAL DAMAGE

The previous sections have dealt with the potential flood damages along the Bow River throughout the City on a district by district basis. The total number of properties that would be affected by overland flooding at the three project floods is shown in Table 2-12.

TABLE 2-12

Distribution of Properties in the Bow River Flood Plain

Project Flood	Houses	Apartment Buildings	Commercial/ Industrial
cfs			
50,000/70,000	407	3	18
80,000/110,000	2,438	85	342
100,000/130,000	2,857	92	405

The potential damages at the project floods are summarized in Table 2-13.

TABLE 2-13

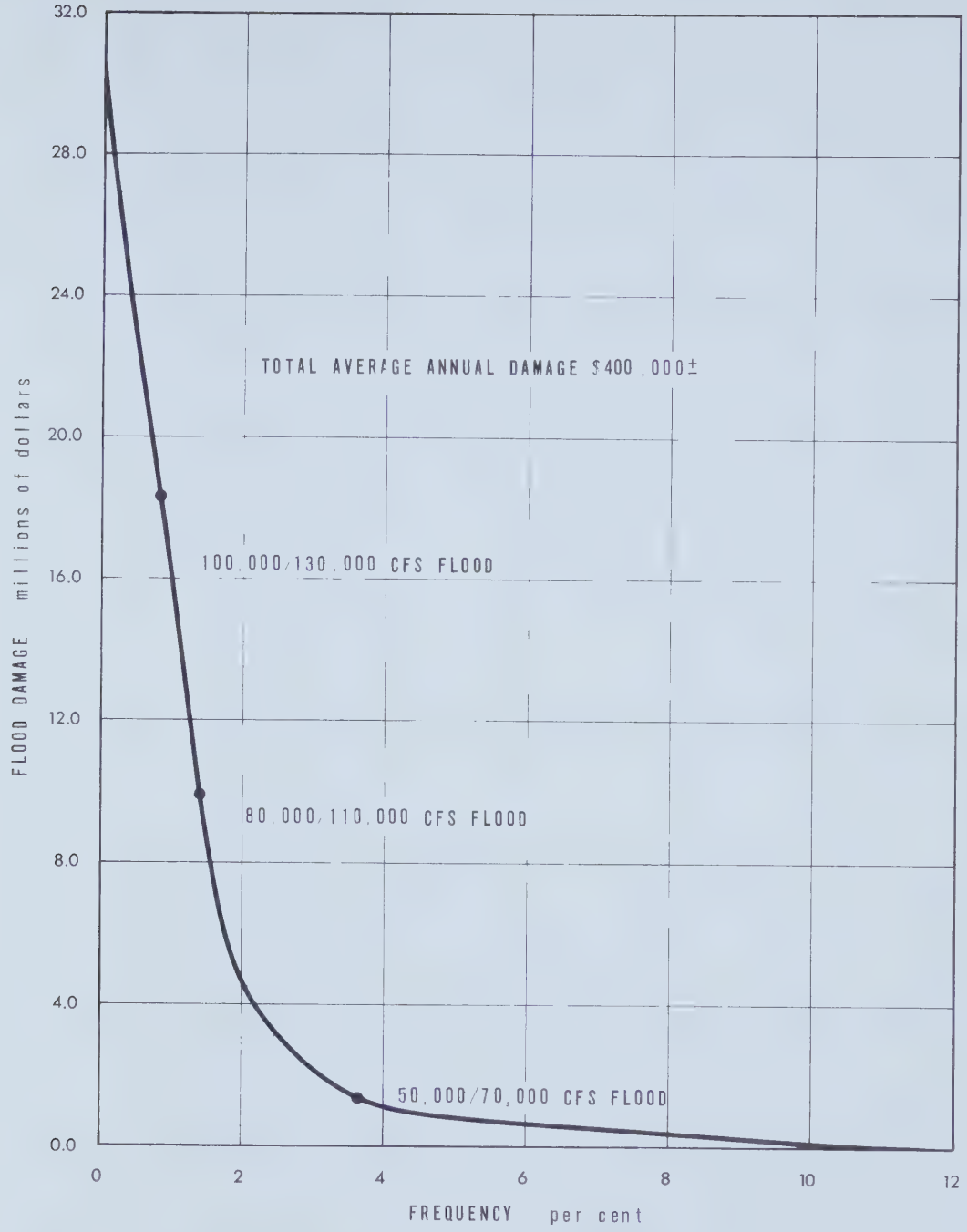
Potential Flood Damages along the Bow River

Area	50,000/ 70,000 cfs	80,000/ 110,000 cfs	100,000/ 130,000 cfs
	$'000	$'000	$'000
Bowness	320	880	1,170
Westmount, Hillhurst, Sunnyside	390	3,770	6,890
Downtown	-	1,540	2,460
Bridgeland	-	440	800
Inglewood, Pearce Estate, Bonnybrook	400	2,300	4,260
Others	50	200	300
Bridges	170	650	1,940
	1,330	9,780	18,470

Using the damages shown in Table 2-13 and the flood frequencies presented in "1.5 Hydrologic Analysis", a curve has been drawn as shown in Figure 2-1. The area underneath the curve represents the average annual flood damage throughout the City which is computed to be $400,000. The average annual damage to residential property represents some 45 per cent of this figure, i.e. $180,000 per annum.

The average annual damage is considerably higher than the $200,000 given in the Report on the Bowness Flood Study, a figure which was derived from a cursory examination only of properties in the flood plain. The principal reasons for the higher figure determined during this study are the greater industrial damages apparent as a result of visits to selected establishments and the greater depths of water estimated on certain areas of the flood plain.

As previously stressed, the potential damages are calculated for present day conditions and no attempt has been made to forecast the extent of future development in the flood plain. As an indication of the increased damage potential that would take place, it should be noted that of the total flood plain area (excluding the river channel) of some 5278 acres at a flow of 80,000/110,000 cfs, only 1122 acres or 21 per cent have been developed to date.



AVERAGE ANNUAL FLOOD DAMAGE
THROUGHOUT CITY OF CALGARY

FIGURE 2-1

PART 3 - MEASURES TO DEAL WITH THE FLOOD HAZARD

CONTENTS

		PAGE
3.1	THE NEED FOR FLOOD PLAIN MANAGEMENT	3-1
3.2	FLOOD PLAIN MANAGEMENT	3-3
	321 INTRODUCTION	3-3
	322 METHODOLOGY	3-5
	.1 Designated Flood	3-5
	.2 Hydraulic Calculations	3-6
	.3 Mapping of the Flood Plain	3-7
	.4 The Two Districts	3-7
	323 LAND AREAS	3-8
	324 PUBLIC ACCEPTANCE	3-10
	.1 Property Devaluation	3-10
	.2 Ulterior Motives	3-10
	.3 Guidelines in Isolation	3-11
	.4 Existence of the Flood Hazard	3-11
	.5 Alternatives to the Guidelines	3-11
	.6 Alteration in Existing District Designations	3-11
	.7 Aesthetic and Environmental Changes	3-11
	.8 Mortgage Monies	3-12
	.9 Boundary Alterations	3-12
	.10 Preparation of Submissions	3-12
	325 POLICY REGARDING RESIDUAL DAMAGES	3-12

PART 3 - (Cont'd)

		PAGE
3.3	ENGINEERING MEASURES	3-14
331	FLOOD STORAGE	3-14
.1	Existing Reservoirs	3-16
.2	Potential Reservoirs	3-17
332	FLOOD FORECASTING AND WARNING SYSTEM	3-18
.1	Benefits and Costs of a Watershed Model	3-19
333	OTHERS	3-21
334	DYKES	3-21
.1	Bowness Area	3-22
.2	Westmount, Hillhurst, Sunnyside and Bridgeland Area	3-23
.3	Downtown Area	3-23
.4	Pearce Estate, Inglewood Area	3-24
.5	Undeveloped Areas	3-25
.6	Summary	3-25
335	CHANNEL IMPROVEMENTS	3-26
.1	Bowness Reach	3-27
.2	Westmount, Hillhurst, Sunnyside Reach	3-27
.3	Downtown Reach	3-29
.4	St. George's Island Reach	3-29
.5	Pearce Estate, Inglewood Reach	3-33
.6	Summary	3-34
336	BANK STABILIZATION	3-36
337	GRAVEL OPERATIONS	3-36

PART 3 - (Cont'd)

		PAGE
338	BRIDGE WATERWAYS	3-37
339	ICE PACK ANCHORAGE	3-40
3310	STRUCTURAL ADJUSTMENTS TO INDIVIDUAL PROPERTIES	3-41

TABLES

TABLE		
3-1	Set-Back Allowances	3-8
3-2	Bow River Land Areas	3-9
3-3	Benefits and Costs of Flood Storage	3-18
3-4	Possible Damage Reductions Resulting from Emergency Action to Residential Structures	3-20
3-5	Westmount, Hillhurst, Sunnyside Channel Improvements	3-29

FIGURES

FIGURE		
3-1	Illustration of Floodway and Flood Plain District Concept	3-4

PLATES

PLATE		
3-1	Existing and Potential Storage Sites in the Bow River Basin	3-15
3-2	Channel Improvements - Westmount, Hillhurst, Sunnyside Reach	3-28
3-3	Channel Improvements - Downtown Reach	3-30

PAGE

PLATE

3-4 Channel Improvements - St. George's Island Reach 3-32

3-5 Channel Improvements - Pearce Estate, Inglewood Reach 3-35

3-6 Recommended Practice for Gravel Operations 3-38

3.1 THE NEED FOR FLOOD PLAIN MANAGEMENT

In the previous parts of this report, the flood hazard in the City of Calgary has been exposed as a problem of significant dimensions which could become more severe in the future. This conclusion is based on the following two findings:

- average annual flood damage in developed areas is estimated to be in the order of $400,000 and appears to be on an upward trend as a result of the redevelopment which is taking place in these areas.

- some 4,156 acres (79 per cent) of the total flood plain area of 5,278 acres (excluding the channel) along the Bow River are in open-space use. It is clear that if this area were developed in a similar manner to presently developed areas, the potential flood damages could be greatly magnified in the future.

There are two fundamental approaches for alleviating this problem; one based on the control of floods through engineering measures such as reservoirs and dykes, and the other based on the control of land-use in the flood plain through administrative measures such as zoning ordinances, i.e. flood plain management. While these approaches are not mutually exclusive and, in fact, are generally complementary, one approach will usually predominate depending upon the economics of the situation. As will be demonstrated in subsequent sections of this part of the report, opportunities to control summer flooding of the Bow River by major engineering works are limited. Moreover, the opportunities that do exist are uneconomic (in terms of potential damages avoided) and, in certain instances, may be socially untenable.

However, it is recognized that economics is not the sole criterion in developing a strategy to deal with the problem. In the following paragraphs, the relative merits of each approach are discussed in the context of the objectives for the development of valley bottom lands which have emerged during this study. The following, not necessarily in order of importance, are the principal objectives:

(1) To minimize the risk of a flood disaster in terms of death and extensive property damage.

(2) To ensure that the costs associated with minimizing the flood risk to new developments in the flood plain are borne by the beneficiaries, i.e. the land and property owners, and not the public at large.

(3) To prevent potentially high maintenance costs resulting from excessive river bank erosion.

(4) To preserve and improve the aesthetic characteristics of the valley bottom.

(5) To minimize the area of valley bottom lands which must be reserved for the passage of flood waters.

As far as the first objective is concerned, both engineering measures and the flood plain management approach may be designed to achieve the same degree of protection. However, whereas engineering measures provide an immediate solution to the problems of flooding, the flood plain management approach is oriented primarily toward new and future developments in the flood plain and does not in itself alleviate the hazard to existing developments.

The second objective will be achieved through the flood plain management approach but may not be by engineering measures, although this will depend on how the measures are financed. Whereas the costs of the flood plain management approach would be borne by the beneficiaries, the costs of implementing major engineering measures are generally absorbed by the public at large who in effect provide a subsidy. Moreover, even if the costs of such measures were borne by the developers, who would presumably pass on a proportionate share of the capital costs to the eventual beneficiaries, the mechanisms for allocating the operation and maintenance costs are not as straight-forward. In addition, it must be stressed that, if reliance is placed on engineering measures to minimize the flood risk, no development should be permitted until these measures have been placed in operation. This means that it may be several years before the capital investment in such measures could be recouped. On the other hand, the costs of protection under the flood plain management approach would be paid for by the beneficiaries as the development proceeds.

The third objective is also more likely to be satisfied through the flood plain management approach which ensures that potential development is set back from the top of the banks. Large-scale engineering measures would lead to more intensive land-use adjacent to the banks which could in turn lead to higher maintenance costs, especially if the measures do nothing to reduce the actual flood flows. As mentioned, it is doubtful if a mechanism could be effectively devised whereby these costs would be borne by the beneficiaries and not by the public at large.

As far as the fourth objective is concerned, the flood plain management approach would be far more effective in achieving this than major engineering measures. Under the flood plain management approach, a green belt would be maintained along the river banks. This would not be the case with engineering measures, such as dyking and channel widening, which would require the removal of many stands of trees. These trees contribute in a large way to aesthetic and environmental values of the Bow River through Calgary. At the same time, however, it should be noted that there is much volunteer growth on the river banks and gravel bars. This growth should be removed to improve the hydraulic efficiency of the river without a significant detrimental effect on aesthetic and environmental values.

As for the fifth objective, engineering measures will result in a greater land area suitable for unrestricted development than the flood plain management approach. However, such measures would likely be expensive

undertakings and an analysis aimed at maximizing the amount of land suitable for development would have to include a comparison of the costs of different engineering works against the land enhancement benefits occurring from each, as well as a comparison with the flood plain management approach. This analysis is best carried out by the beneficiaries of such measures.

In summary, both approaches offer certain advantages and disadvantages. However, the lack of economically feasible and socially acceptable large-scale engineering possibilities points strongly to the need for flood plain management. The appropriate strategy in Calgary will comprise a mix of more modest engineering measures coupled with firm management of developments in the flood plain. The latter will be the key element in a course of action to minimize potential damages and hardships due to flooding and is discussed in detail in the following sections of this report.

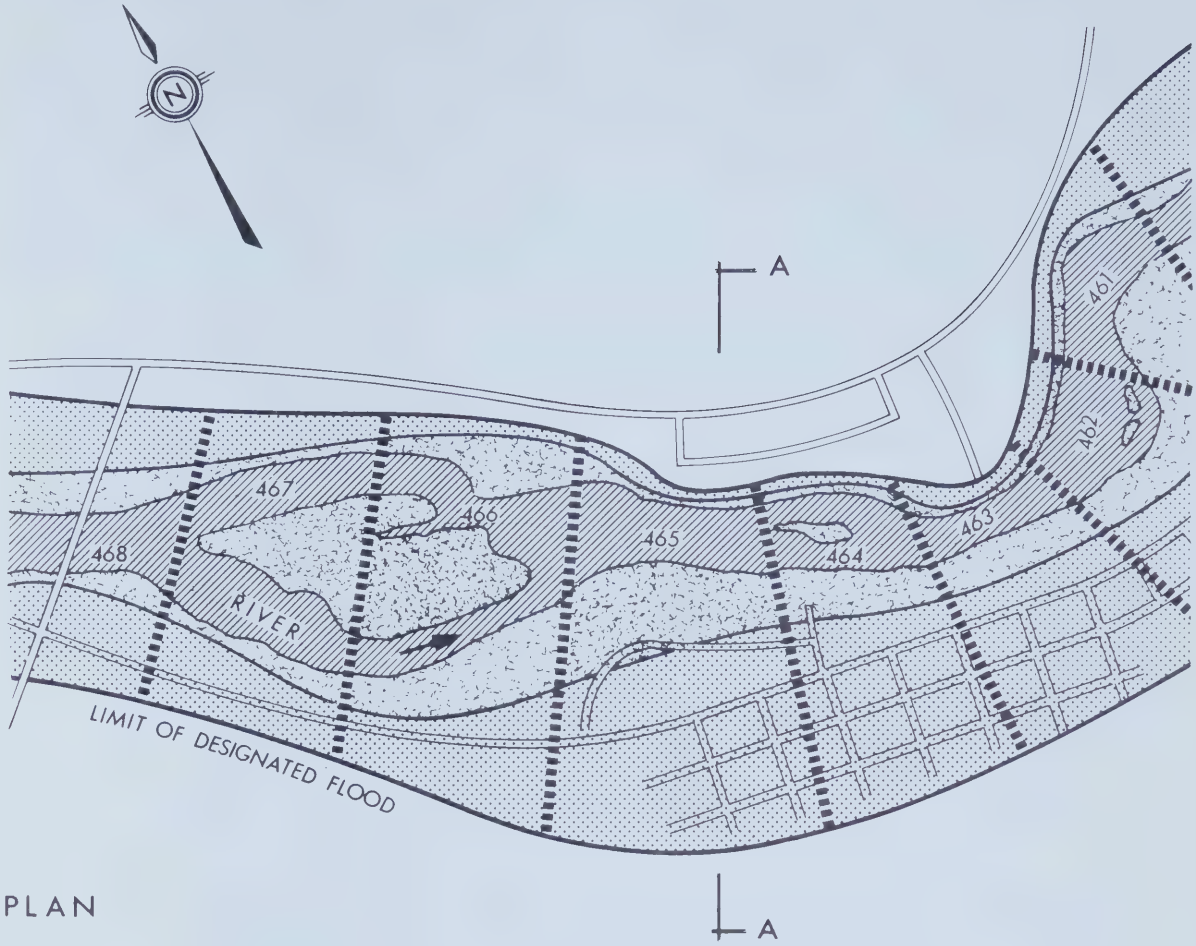
3.2 FLOOD PLAIN MANAGEMENT

In the context of this section of the report, the term flood plain management is used to cover only those measures of an administrative nature which are aimed at managing development in the flood plain so as to reduce the hardship (loss of life, community disruption and public health) and to minimize the economic losses in the event of a major flood. The hardship factor is difficult to quantify but must be taken into account when evaluating alternative measures. Furthermore, over and above strictly economic criteria, there is a need to minimize the possibility of a disaster of the magnitude that could occur in the event of repetition of the flood of 1897.

Public acceptance of the plan presented for flood plain management will depend upon the recognition of the value of the plan in reducing damage potential and hardship, primarily through controls and restraints on flood plain development. Severe flooding has not occurred in recent memory and development to date has been undertaken with minimal restraints. There is a general lack of concern about the flood hazard in Calgary. Efforts to achieve a positive awareness of the hazard by community leaders and the public will be needed to successfully adopt and implement the plan. During the course of the study, several points of concern have been expressed and, prior to public acceptance of the plan, it will be necessary to alleviate these concerns. The points of concern are discussed in "325 - Public Acceptance".

321 INTRODUCTION

The need for flood plain management through the City has already been recognized and a two district concept to achieve this has been adopted in principle by the City of Calgary Council in September 1971. The two districts, which are commonly referred to as a "floodway" and "flood plain", are illustrated in Figure 3-1 and are defined as follows:



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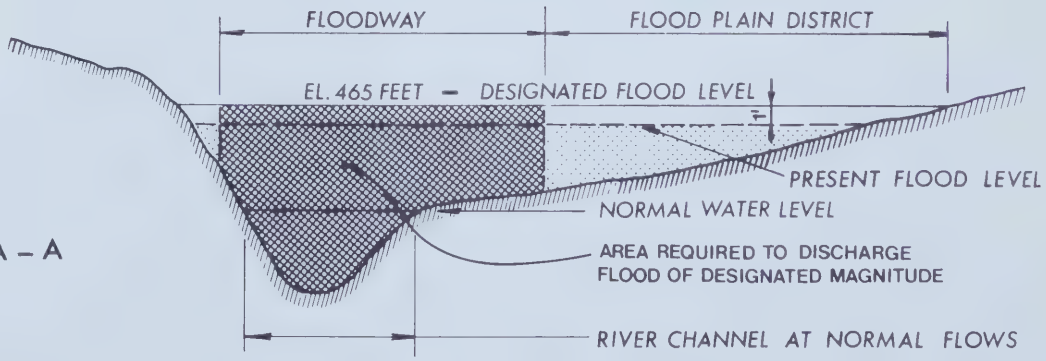

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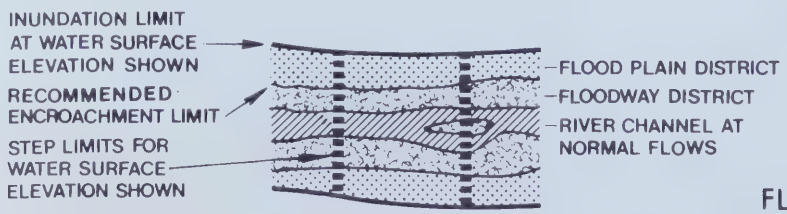

FIGURE 3 – 1

ILUSTRATION OF
FLOODWAY AND FLOOD PLAIN
DISTRICT CONCEPT

Floodway District - The present channel plus those portions of land which are needed to convey a flood of designated magnitude without unreasonably raising the upstream water levels above the natural levels that would exist if the channel were well maintained.

Flood Plain District - Those additional portions of land over and above the floodway district not needed for the conveyance of the designated flood but which are, nonetheless, subject to inundation.

The guidelines for the establishment of these districts were presented in the Report on the Bowness Flood Study and one of the principal aims of this expanded study has been to apply these guidelines to the whole of the flood plain throughout the City.

322 METHODOLOGY

The establishment of the flood plain management concept for the wise and economic development of flood plain lands comprises four basic steps as follows:

(1) Determination of the magnitude of the flood which should be used, i.e. the designated flood.

(2) Determination of the water surface elevations association with the flood of designated magnitude.

(3) Relating the calculated water surface elevations to ground elevations so as to determine the extent of inundation at the designated flood.

(4) Determination of the extent to which encroachment and building in the flood plain may take place without works of an alleviating nature.

These four steps are discussed in detail in the following sections.

.1 Designated Flood

Selection of the flood to be used in establishing the limits of the floodway and flood plain districts and other related parameters is an important step in implementing the flood plain management concept. It is essential that the magnitude of the designated flood be reasonable, i.e. neither too high so as to impose an unduly restrictive limitation on potential development, nor too low so as to be ineffectual in reducing potential damages and hardships if development is allowed to proceed.

Two basic approaches have been used in other areas to establish a designated flood of reasonable magnitude. These approaches are:

- to use the highest recorded flood

- to use a flood with a return period of 1 in 100 years as determined by hydrologic analyses.

The first approach has the advantage that the flood of record is an historical fact, and, as such, could be easily substantiated if it were ever argued that the implementation of the flood plain management concept was unduly restrictive. This approach is generally only valid when a long period of recorded streamflow measurements is available (60 years or more).

The second approach requires a statistical computation and can lead to a wide variation in results. This variation is a function of the methods of frequency analysis and the methods used to extrapolate from a short period of record to a longer period of time. While most are in relatively good agreement in the middle range of return periods, say between 1 in 2 years and 1 in 50 years, (depending upon the length of the period of record), they begin to diverge rapidly at the higher return periods.

The highest recorded flood on the Bow River through Calgary had a maximum instantaneous peak of 80,000 cfs above the Elbow River and an estimated peak of 110,000 cfs below the Elbow River. By hydrologic analyses, the return period of this flood is approximately 1 in 70 years. Implementation of the two district concept for this flood would provide an adequate degree of protection and would be generally in keeping with similar situations elsewhere. It has, therefore, been adopted as the designated flood of the Bow River in Calgary.

.2 Hydraulic Calculations

As briefly described in "1.5 - Delineation of the Flood Plain", computerized hydraulic calculations have been carried out to determine water surface elevations and other related parameters for various flows (project floods) selected at the start of these studies. This section is concerned only with these parameters at the designated flood flows of 80,000/110,000 cfs along the Bow River. The calculations highlight the constriction to flow posed by some bridges and their approach embankments.

The average slope of the Bow River through the City of Calgary is 0.0018 (i.e. 9.3 feet per mile). This relatively steep slope in combination with the hydraulically efficient channel section along most of the river leads to average channel velocities in the range 8 to 15 fps and average velocities in the overbank sections in the range 1 to 3 fps. Stage of the designated flood above that of normal low flow in the river of 3,300 cfs will be in the range 12 to 16 feet.

From a hydraulic standpoint, the mode of passage of the designated flood flow along the Bow River is different from that along Fish Creek. Along the Bow, notably upstream of Bonnybrook Bridge, the average flow through the flood plain will seldom exceed 20 per cent of the total flow whereas along Fish Creek, the flow through the flood plain will often be of the order of 50 per cent of the total flow, i.e. the flood plain of Bow River is much less important for the conveyance of the designated flood than that of Fish Creek.

.3 Mapping of the Flood Plain

The areal extent of flooding was determined in the main by relating the designated flood profiles to specially prepared topographic maps. This approach was supplemented by a detailed examination of aerial photographs, by reference to surveyed cross-sections and by field reconnaissance. A surcharge of 1 foot was added to the profiles calculated to allow for extraordinary high water levels and to make the degree of protection afforded equivalent to that provided in similar situations elsewhere.

Experience elsewhere has shown that accurate delineation of the flood plain in developed areas is essential if the flood plain management approach is to be implemented and applied without major objections, resistance to the approach often being most strenuous from property owners close to the boundaries of the flood plain. Specially prepared topographic maps with 2 feet contour intervals and field reconnaissance have been used to establish the limits of the designated flood plain as accurately as possible.

.4 The Two Districts

The key to the two districts is the establishment of encroachment limits, i.e. the limit of obstruction to the designated flood flow. These limits are established by assuming that the area landward (outside) of the limits will be ultimately developed in such a way as to be unable to convey any portion of the designated flood. The channel and adjoining flood plain between these limits, i.e. the floodway district, would be maintained as open space in order to convey the designated flood without unreasonably raising upstream water elevations. Where the floodway district has been established in this manner elsewhere, the allowable rise in water surface elevations above natural conditions has been set in the range 0.5 to 1.0 feet. There are sound reasons for limiting the rise to these modest values. In the first instance, a stage rise much greater than one foot at the designated flood flow would be accompanied by an increase in channel velocities which could greatly increase the possibility of channel instabilities leading to changes in channel alignment. Moreover, along reaches where development on the flood plain has already occurred, a stage rise of greater than one foot above natural conditions would almost certainly lead to an appreciable increase in the damage potential.

A criterion of 1 foot was adopted for the Bow River and Fish Creek and various degrees of encroachment were examined until the one foot criterion was achieved. The encroachment limits so determined take into account factors which affect the hydraulic efficiency, such as relative ground levels on both sides of the channel, and the types and resistance to flow of impediments on either side of the channel. In most cases, these factors will not result in equal distances or areas between encroachment limits on both sides of the channel, but will result in the minimum area of land reserved for floodway district.

In the case of the Bow River, especially upstream of the Bonnybrook Bridge and except where major landfill into the river channel has occurred, encroachment to the banks would generally result in a stage rise less than

1 foot. In these circumstances, it is proposed that the floodway limit be established up to 100 feet back from the top of the bank, the extent of this set-back being contingent upon the velocity of flow in the channel and any bank protection provided. Where no bank protection is provided, it is proposed that the set-back allowance from the top of the bank to the nearest point of a building or structure be as shown in Table 3-1.

TABLE 3-1

Set-Back Allowances

Average Channel Velocity	Approximate Set-Back
ft/sec	ft
< 8	0
8 to 10	25
10 to 12	50
12 to 14	75
14 to 16	100

The two districts, which are referred to as the Floodway District and Flood Plain District, are shown on the maps contained in Part 5 of this report. Details of recommended guidelines which should accompany these maps are presented also.

323 LAND AREAS

Table 3-2 details the land areas occupied by the Floodway and Flood Plain Districts along the Bow River. Excluding the river channel, the Floodway District occupies a significant part of the total flooded area at the designated flood - roughly 30 per cent.

While this infers that a substantial part of the flooded area is unsuitable for development, it should be noted that this area encompasses many small isolated land pockets between valley walls and channel banks, as well as much low-lying land already designated as park land in perpetuity. The difficulties of providing services to some of these pockets may well preclude their potential development and thus a major proportion of the Floodway District may be naturally unsuitable for development irrespective of

the recommended zoning. In this respect, it is stressed that the flood hazard is only one factor, albeit an important one, to be considered in assessing the development feasibility of flood plain lands.

TABLE 3-2

Bow River Land Areas

Land Description	Upper Reach, 85th St. N.W. to Bonnybrook Bridge		Lower Reach Bonnybrook Bridge to Fish Creek		Total Study Reach	
	Acres	%	Acres	%	Acres	%
Total flooded area including channel	3,076	100	3,279	100	6,355	100
Total flooded area excluding channel	2,376	77	2,902	88	5,278	83
Channel area	700	23	377	12	1,077	17
Floodway District	1,360	44	1,302	40	2,662	42
Flood Plain District	1,716	56	1,977	60	3,693	58

NOTES:

1. The extents of the Floodway District and Flood Plain District are shown on Plates 5-2 to 5-31 inclusive in Part 5.
2. The Floodway District is inclusive of the channel area.
3. The total flooded area is for a flood of 80,000/110,000 cfs plus 1 foot surcharge.
4. Of the Flood Plain District, approximately 1,071 acres (63 per cent) above Bonnybrook Bridge and 42 acres (2 per cent) below Bonnybrook Bridge have been developed intensively.

is definitely not the case. The guidelines are intended solely to minimize the risk of potential damages and hardship due to flooding and this point must be stressed prior to public acceptance of the plan.

.3 Guidelines in Isolation

In discussing the guidelines as they affect certain parts of the City, it is important to stress and clarify that all flood plain lands will be similarly treated. The application of the guidelines to one area in isolation would be inconsistent as well as unjust.

.4 Existence of the Flood Hazard

Many persons do not believe that there is a flood hazard because of the lack of major summer floods since 1932, their belief that adequate protection is provided by dams on the river and their own evaluation of the hydrology of floods. This study and others have confirmed, through review of past records and by analysis of meteorological and other factors which influence the occurrence of flood flows, that a real hazard does exist. While Bearspaw Dam provides some protection against winter flooding, this dam and others on the river can do little to reduce major summer floods. Convincing flood plain occupants of the existence of the hazard, and hence the need to take the precautions embodied in the guidelines, may be the most difficult task facing administrators of the flood plain, especially as the impetus for guidelines similar to those recommended is usually provided by a large flood.

.5 Alternatives to the Guidelines

As will be discussed in subsequent sections of this report, the guidelines are only part of an overall strategy to minimize potential damage and hardship in the long term. In arriving at this strategy, consideration has been given to other measures both of a major and minor nature, and some of these are recommended for implementation in conjunction with the guidelines.

.6 Alteration in Existing District Designations

Except for the establishment of the Floodway District generally occupying a narrow strip of land along the river, the guidelines would not alter the existing district designations. In the Flood Plain District with the exceptions of schools, hospitals, nursing homes, and other places of assembly, the permitted and specified uses would be as determined by the Development Control Bylaw, i.e. the guidelines for this area would be superimposed over the bylaw and pertain primarily to structural requirements to be incorporated in the Building Code Regulations.

.7 Aesthetic and Environmental Changes

The guidelines would not alter the aesthetic and environmental characteristics of the river, characteristics which are highly valued by property owners close to the river and which are important to all residents

of the City of Calgary. In comparison, dyking and major channel improvements would almost certainly bring about substantial devaluation of the aesthetic amenities.

.8 Mortgage Monies

Preliminary discussions with lending agencies have indicated that mortgage monies would be made available for developed properties as at present and, in fact, might be made even more readily available for new developments if they are built to the standards and elevations proposed in the guidelines.

.9 Boundary Alterations

It should be noted that the recommended district maps and guidelines are flexible regarding alterations to the boundaries of the Floodway and Flood Plain Districts if it can be demonstrated that:

- a flood control project of the Federal, Provincial or City Government or of a private person will alter or has altered the flood hazard, or

- flood data compiled subsequent to the enactment of the guidelines indicate that the boundaries of the districts as shown on the district maps of the city have been incorrectly located. This is a concern that has been raised by the Urban Development Institute, Calgary, during the course of the study.

.10 Preparation of Submissions

It is proposed that implementation of the guidelines not be undertaken until a series of public meetings explaining the flood plain management plan has been held. This course of action will allow ample time for interested parties to prepare submissions but hopefully most of their concerns can be discussed and dealt with ahead of the hearings by the information programme proposed in Part 4 of this report.

325 POLICY REGARDING RESIDUAL DAMAGES

Unless full protection against the maximum probable flood is provided to flood plain areas, residual damages from flooding will occur albeit infrequently. Since full protection is seldom economically justified, and certainly this is so in the case of the City of Calgary, then an indemnification policy towards these residual damages should be considered, especially when the key element of the strategy for reducing potential damage is the long-term flood plain management approach. Such a policy should be based on potential flood loss considerations not only for the City of Calgary but also for other flood plain areas throughout the Province of Alberta.

Several alternative methods might be considered to provide indemnification for losses suffered through floods and these methods include:

Alternative A - flood insurance by conventional means through private or governmental agencies.

Alternative B - special taxes on flood plain developments which are set aside for the flood event.

Alternative C - disaster funds which are established by governmental agencies to deal with losses as and when they occur.

At first sight it would appear that, in view of the relatively modest average annual flood losses forecast to occur in the City of Calgary, some form of indemnification programme may be one of the more viable adjustments to flooding. However, indemnification is essentially a palliative rather than a cure. It can play an important role in encouraging individual structural adjustments and emergency action, and it will have its place in many programmes to reduce the potential hardships due to floods, but it cannot replace the introduction of more positive measures to reduce the potential losses.

A conventional form of flood insurance (Alternative A) for the whole flood plain in the City of Calgary is not feasible unless it is integrated into a national or at least provincial scheme. There is no opportunity to spread the risk unless other perils are included. When the flood occurs, all the residents in the flood plain will be affected, and all will claim simultaneously. There is no nation-wide flood insurance scheme and none is under consideration. For the present, therefore, the problem in the City of Calgary must be viewed in isolation.

Consequently, an indemnity scheme must take the form of a government sponsored fund either supported by a special tax assessment against the potential beneficiaries (Alternative B) or else by the general tax revenue of the City, the Province or both (Alternative C). The choice between these alternatives is complicated by precedents. In other areas where flood disasters have actually occurred, compensation for damages has been paid by Federal, Provincial and Municipal Governments and by public subscription to varying degrees. On this basis it is reasonable to assume that, in the event of a major flood in the City of Calgary, the two senior levels of government would share responsibility with the City. However, this action by the two senior levels of government might not be taken in the case of less than catastrophic floods, i.e. floods in which the damages are serious but not wide-spread, so that there will still be cause for considering an indemnity scheme which covers the individual against all significant flood damage.

The advantage of Alternative B, a scheme based on special tax assessments on flood plain developments only, is that it places the financial burden on those who would benefit, rather than on the community or province as a whole, as in Alternative C.

The tax assessments could be evaluated on a property by property basis taking into account both risk and potential damages. The procedure adopted would be similar to that which has been used to calculate the total average annual damage in the City. This method is readily applicable to residential structures but commercial and industrial establishments would have to be evaluated on a more detailed basis because of their wide variation.

For political reasons, the assessment for existing developments in the flood plain may have to be subsidized. On the other hand, new developments in the flood plain would bear the full assessment which will, in effect, act as an incentive for the developer to minimize the risk of flood damage. Even so, such a scheme could encounter a great deal of opposition from property owners in the flood plain.

Moreover, it should be appreciated that any insurance scheme or special tax on flood plain developments involves an administrative cost which must be set against the benefits of such a scheme.

In conclusion, it is suggested that, while a policy toward residual damages, particularly along the lines of Alternative B is desirable, such a policy should not be implemented at this time. The course of events in the future may alter the situation and warrant more detailed study of the alternatives discussed at a later date.

3.3 ENGINEERING MEASURES

Engineering measures are measures of a protective nature which, when implemented, directly reduce the risk of flooding. Falling into this category are measures with a localized effect, such as dykes and channel improvements, and measures with a widespread effect which benefit the whole of the flood plain, such as detention or storage reservoirs and a flood warning system.

331 FLOOD STORAGE

The report on the Bowness Flood Study included a preliminary investigation of utilizing existing upstream reservoirs or developing new reservoirs for flood control purposes, sufficient work being done to indicate where more detailed studies might be warranted. The calculation of flood control benefit has been extended throughout the City, but no other new information has been included in the present study. The paragraphs which follow are, therefore, largely a re-statement of the conclusions reached in the earlier report and are included herein to provide the complete picture. The existing and potential reservoirs in the Bow River Basin are shown on Plate 3-1.

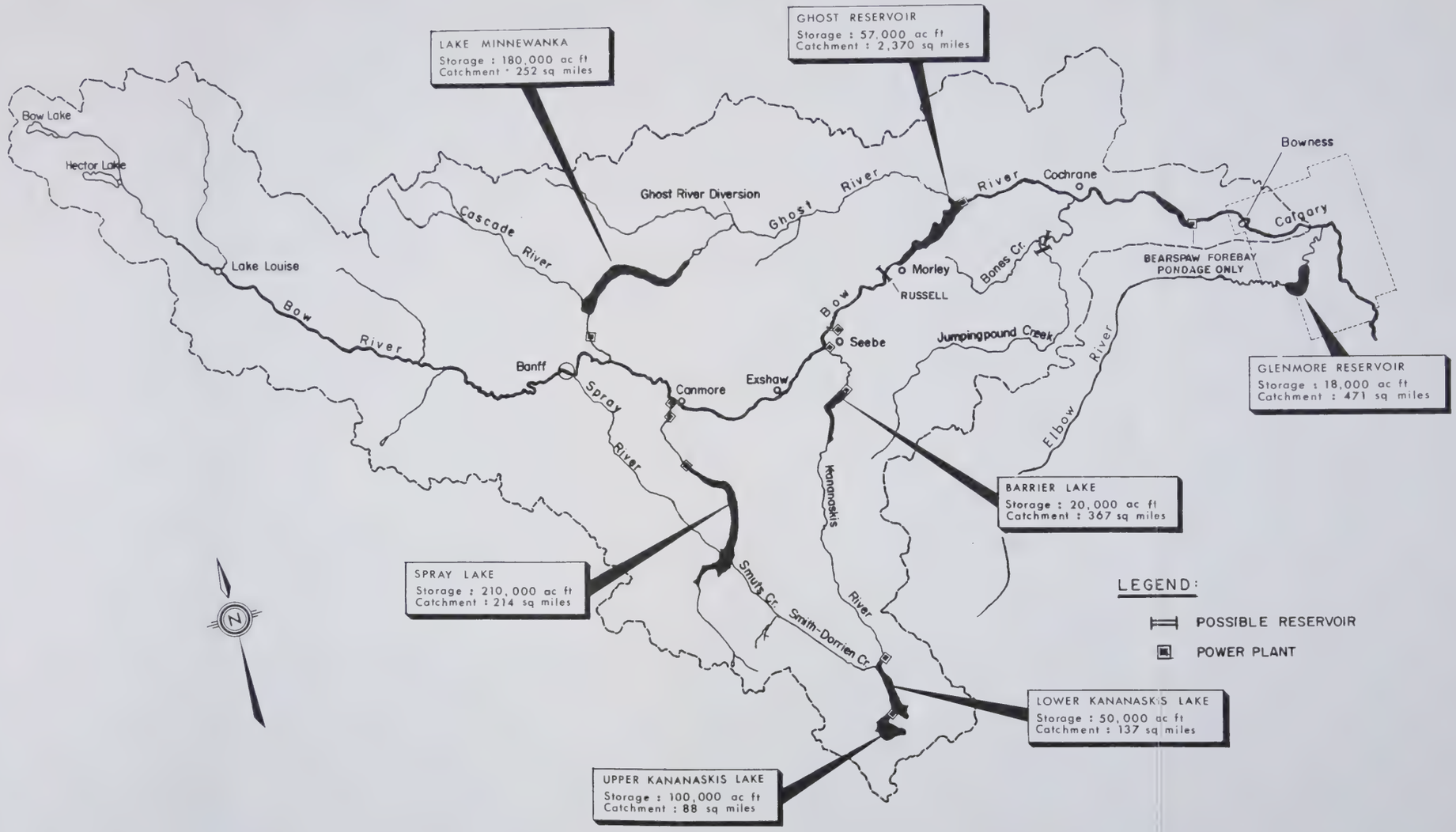

PLATE 3 – 1

EXISTING AND POTENTIAL
STORAGE SITES
IN THE BOW RIVER BASIN

.1 Existing Reservoirs

Calgary Power Ltd. owns and operates 11 hydroelectric plants in the Bow River Basin. Multi-year flow regulation is provided by four large storage reservoirs located in the headwaters of the basin on the Upper and Lower Kananaskis Lakes, Spray Lakes and Lake Minnewanka. Smaller amounts of storage are provided at the Barrier Plant on the Lower Kananaskis River and at the Ghost Plant on the main stem of the Bow.

In normal operation, water is withdrawn from the four large storage reservoirs during the winter to supplement the declining natural streamflows, and the reservoirs are then refilled during the spring and summer. Thus, the operation of these reservoirs for flood control and power is compatible. It must be stressed, however, that these reservoirs would have affected only a small reduction of historic peak flows, had they been in existence when these floods occurred because the total drainage area controlled by them is less than 28 per cent of the total drainage area above Calgary and because they were receiving snowfall at the time of the floods in Calgary in those instances where such information is available. Attempts to increase the flood control benefits by greater drawdown of the storage would tend to be incompatible with power operations and with the growing recreational use of these lakes.

The Barrier and Ghost Lakes storages are used to take care of minor daily and weekly fluctuations in load requirements and generally operate near their fully supply levels. Barrier Lake has a relatively small storage volume and, in common with the major reservoirs further upstream, controls a small proportion of the flood-producing drainage area. Ghost Lake has a larger storage volume and, if accurate forecasts of flood inflows could be obtained and the sluiceways and spillways operated to effect flood control, it could provide a somewhat greater reduction in the peak of a flood flow through Calgary than now occurs with normal hydroelectric power operating procedures. The principal problems in respect to this arise because of the nature of the flood hydrograph. Because it is induced by rain falling on relatively steep ground, the hydrograph is very sharply peaked, and little time is available to take required corrective actions, either at the Ghost Dam or in Calgary. At present, the Ghost spillways are all controlled by stoplogs which require a considerable amount of time to remove, particularly if the work is being done under storm conditions. They likewise require a considerable length of time to be replaced, so that an error in flood forecast which causes the logs to be withdrawn too soon could result in difficulty in refilling. In order to make the dam fully effective for flood control storage, it would probably be necessary to spend a large sum of money to modernize the spillways and provide motor operated gates. Specific operation for flood control would require that water levels fluctuate more widely and be lower, on average, than the power operating procedures do. This would cause a small loss of energy and would also conflict with recreational use of the lake.

With regard to the need for accurate forecasts of flood inflows, the use of a computerized watershed model appears to offer considerable promise. Over the past 10 years or so, sophisticated techniques for

simulating streamflows using such models have been developed. By linking the model to a network of meteorological and streamflow gauges which relay the information continuously or at frequent intervals to a data centre, a relatively accurate forecast of the flood peaks in the watershed can be made. The network would monitor the storms as they occur so that progressively less reliance would be placed on meteorological forecasts as the storm develops. The model would rapidly interpret the data into forecasts of flood volumes, peaks and timing. Studies of the various systems now in use(1) indicate that a commercial system based on the Stanford Watershed Model is the most feasible technique for producing accurate and early quantitative flood forecasts on the Bow River. The possibility of supplementing the existing procedures with this model is discussed in more detail in "332 - Flood Forecasting and Warning System".

A quantitative assessment of the incremental benefits resulting from improved forecasting and flood control operation at Ghost is impossible because the procedures have not been tested by a large flood and there is no way of estimating to what extent the objectives might be achieved, using either existing procedures or a system supplemented by a watershed model.

Although there is little doubt that a properly designed, calibrated and utilized watershed model would be a very useful tool, it is not possible to state that its cost would be warranted solely from the standpoint of the operation of Ghost Reservoir during floods. There are other incremental benefits and these must be considered before a judgement of the economic viability of the watershed model can be made. (See "332 - Flood Forecasting and Warning System".)

All other plants in the system operate on run of river flows as modified by any storage which exist above them. One of these plants, Bearspaw, has been incorrectly attributed by many to be the principal reason for the lack of summer flooding in Calgary in recent years. This plant has a very small forebay. If it were possible to completely drain it ahead of a flood, the total volume of storage made available would be only some 5 per cent of the volume of a flood comparable in magnitude to that of 1897. Obviously, Bearspaw can have little effect on the peak of a flood flow through Calgary.

.2 Potential Reservoirs

Of the potential reservoir sites examined, the sites on the Bow at Russell and on Jumpingpound Creek upstream of Bones Creek appear the best of possible new developments (see Plate 3-1). A cursory examination has indicated that other possible sites, for example, on tributaries such as the Ghost and Kananaskis Rivers are not as favorable as the Russell and Jumpingpound Creek sites.

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(1) Since these studies were completed, the Water Survey of Canada has studied a system based on the SSARR model developed primarily by the U.S. Corps of Engineers. The suitability and availability of this model should be investigated as a first step in any further consideration of implementing a flood forecasting system.

The feasibility of developing new storages as a measure for flood control is, of course, determined by the extent to which downstream damage is prevented. It should be noted that reservoirs designed for flood control only usually cannot be used to meet other possible demands, such as power generation and irrigation, recreation, and hence, it is difficult to attach to such schemes any benefits other than potential damage prevented.

The costs and benefits (i.e. average annual damage prevented) of upstream regulation at the Jumpingpound and Russell sites are summarized in Table 3-3. This table has been up-dated from that presented in the Bowness Report to reflect the detailed potential damage estimates made for the whole City and the lower interest rates on capital at the present time.

TABLE 3-3

Benefits and Costs of Flood Storage

Storage	Average Annual Residual Damage	Average Annual Damage Prevented	Annual Cost
	$'000	$'000	$'000
Jumpingpound	280	100	300
Jumpingpound & Russell	90	290	1,700

Clearly, the construction of new flood storage reservoirs at the sites indicated is uneconomic and should be dismissed from further study.

332 FLOOD FORECASTING AND WARNING SYSTEM

The extent and effectiveness of emergency action in anticipation of a major flood is largely dependent on how early the warning is given. Time is needed both to relay the warning to the residents in the flood plain and to allow them to react. On the other hand, false or inaccurate warnings will quickly result in a loss of confidence in the warning system and must be avoided.

At present, flow forecasts are made cooperatively by the government agencies and organizations monitoring conditions in the watershed. The forecasts are based on meteorological forecasts, observations in the watershed and data received from power plants, reservoirs, streamflow stations, meteorological stations and snow courses both within the basin and in the region as a whole. Because of the extensive development of the river and its tributaries, the course of a flood can be monitored in considerable detail.

The only place that data collection is centralized at present is at the Seebe control centre of Calgary Power, Ltd.

In "331 - Flood Storage", the possibility of supplementing the existing forecasting procedures with recently developed techniques involving a computerized watershed simulation model is raised and it is suggested that application of these techniques to the Bow River Basin may provide useful information for operating Ghost Reservoir during a flood. The watershed model would process data and make quantitative predictions of flood flows.

In the report on the Bowness Flood Study and in the Appendix, flood forecasting is explored in detail and it was concluded that the watershed simulation model HSP/Floods developed by Hydrocomp International, Inc. holds considerable promise for producing more accurate and reliable forecasts of potential floods, both at Ghost Reservoir and in the City of Calgary. It was recommended, therefore, that detailed discussions with all the agencies and organizations monitoring conditions on the watershed and expected to play a role in the implementation of a model be initiated with a view to confirming its feasibility and resolving any outstanding questions. Progress in this direction has been made by the Water Survey of Canada (W.S.C.) who have been studying a system based on the SSARR model which has been developed primarily by the U.S. Corps of Engineers. W.S.C. believe that, with modifications this model can adequately simulate the flood runoff process in the Bow River Basin. However, additional input data would be required to produce flood forecasts with a sufficient degree of accuracy and timing.

It was also recommended in the Bowness report that a flood forecasting centre be established by a federal or provincial agency and that step-by-step procedures for the issuing of flood warnings and other action by the City should be drawn up. The results of the present study have reinforced these conclusions and recommendations as discussed in the following section.

The stage-damage curves used in Part 2 to estimate potential damages do not account for emergency action taken by residents in the flood plain when given advanced warning of an impending flood. In order to evaluate the savings that might be achieved, damage reduction criteria as shown in Table 3-4 have been applied to the City of Calgary. The feasibility of achieving the reductions indicated in Table 3-4 will depend, in large measure, on efforts to make the property owners aware of the magnitude of the flood hazard and aware of the need to take emergency action when flood warnings are given. The perception and attitude survey indicated that, at present, the individual owners are complacent and that there might be little effort on their part to take any action in the event of a warning. The need for a programme of public education and information is explored in more detail in Part 4 of this report.

TABLE 3-4

Possible Damage Reductions Resulting from Emergency Action to Residential Structures

Type of Flooding	Damage Reduction Contents	Structure
	Per Cent	Per Cent
Basement	20	5
Water 0 - 1 ft above 1st floor	20	10
Water 1 ft above 1st floor	15	0

Purposely low percentages for damage reduction have been assumed compared with those suggested in the literature. However, it should be noted that residents of Calgary have little experience in taking emergency action. Their efforts will be limited to flood fighting in individual establishments, the elevation of certain goods and equipment, and the temporary protection of equipment.

Using the criteria shown in Table 3-4, the average annual damage reduction which might be achieved by emergency action is estimated to be in the order of $40,000.

Although only a few hours advanced warning can be given using the present forecasting procedures without risking a false alarm, it may be sufficient to achieve a substantial proportion of the damage reduction. Moreover, establishing a forecasting centre and formalizing the procedures for disseminating the forecasts and issuing warnings, which has been recommended, will ensure that emergency action will be as effective as possible given the limitations of the lead time available. As in the case of operation of Ghost Reservoir, there is no way of estimating the incremental benefit that would be achieved by employing a watershed model to permit earlier and more accurate forecasts.

The capital cost of installation and annual operating costs of HSP/Floods have been tentatively estimated at $81,000 and $12,350 respectively assuming that it would be operated by an existing federal or provincial agency. Despite the difficulty in estimating the incremental benefits which would accrue to the employment of a watershed model, it seems highly likely that these will justify the costs. This will certainly be true if the staffing requirements for operating the model can be met without hiring new people and the costs are not charged against the forecasting system. Whether or not such a model is employed, there are strong reasons to establish a forecasting centre with the necessary staff.

333 OTHERS

Other possible measures for reducing the effect of flood flows on the study reach and downstream reaches include floodways and watershed management techniques.

A floodway around the Bowness district and other downstream districts would be, by inspection, extremely difficult if not impossible to implement. The general topography of the land and the extent of present development are such that further investigation of this alternative is not warranted.

Watershed management techniques for reducing flood flows include measures aimed at reducing volumes of runoff and the times of concentration of such runoff. These techniques would primarily be concerned with land-use changes and might, for example, include changes in agricultural practices or forestation of areas ravaged by fires. It is believed that land-use changes in the Bow River Basin upstream of Calgary have had little effect to date on the instantaneous peak flood flows at Calgary and, consequently, watershed management techniques are unlikely to achieve much from the standpoint of flood control.

334 DYKES

Dyking of developed areas throughout the City of Calgary is prominent along sections of low river bank where the river is subject to ice packing; from Crowchild Bridge downstream to St. George's Island. Because of existing buildings and the need to preserve mature trees, much of this dyking has been located along the river's edge and, in several locations, extended into the main channel of the river. Adequate erosion protection of the dykes against summer flood flows has not been provided.

The dykes, in conjunction with other works, were built to counteract winter flooding with attendant low velocities of flow. To this end, they have proven to be very effective. Many storm sewers with gated outlets breach the dykes and, in winter, the gates are closed to prevent the back-up of water.

Under major summer flood conditions, the existing dykes which are pervious would be almost totally ineffective in preventing damage to adjacent properties in the flood plain. Their slopes are mostly oversteep, partially unprotected, and would be damaged by erosion prior to the arrival of the flood peak. Moreover, even if they withstood the flood, the back-up of water along the storm sewers which enter the river at right angles to the flow would cause inundation. Closing the gates of the sewers in summer would generally not be practical because of the runoff originating behind the dykes. Thus, in evaluating the feasibility of protecting developed areas through dykes, the following three main criteria should be considered:

- the extent of realignment, regrading and riprap protection necessary to make the existing dyke system effective against major summer floods.

- the modifications required to the drainage system behind the dykes.

- effects on aesthetic and environmental values.

Dyking is only as good as the project flood for which it is designed and should be supplemented by other measures such as the zoning ordinances and building code amendments. Moreover, dykes and, for that matter, reservoirs can engender a false sense of security and in the event of the project flood being exceeded, the resulting damage could be much greater than would occur without them. Also, dykes would not solve the problems of seepage experienced by the owners of properties in low lying areas adjacent to the river. Seepage leading to the flooding of basements is a common occurrence in Calgary during periods of high prolonged, river stages. On the more positive side, however, the benefits from dyking in developed areas are immediate whereas those of the flood plain management concept are realized mostly in the long term. Primarily, for this reason, the benefits and costs of upgrading the present dyke system (or building a new system) to protect developed areas in Calgary from summer floods are analyzed in some detail in the following sections of this report.

.1 Bowness Area

An effective dyke system for the Bowness Area, which would provide protection against a flood of similar magnitude to that of 1897, would require the purchase of land along the water's edge from Twin Bridges downstream to the Highway No. 1 Bridge. Dykes constructed along this reach would have to be heavily riprapped to prevent erosion caused by velocities of up to 15 feet per second at flood flows. The estimated cost of providing such a dyke to protect the Bowness Area is approximately $1.0 million including the clearing and purchase of land. The average annual damage prevented by this measure would be in the order of $30,000.

Thus, on economic grounds alone, major dyking of the Bowness Area does not appear worthy of further consideration. Also, the feasibility of major dyking along the reach diminishes even more if the potential opposition to this measure is taken into account. The opposition to dyking would come from the property owners fronting the river who would suffer an intangible loss to the amenity value of their properties. Views of the river would be obscured and the removal of many trees would be necessary in order to achieve the desired dyke alignment.

Improved dyke protection (including improvements to the local drainage system) of the Bow View Nursing Home costing in the region of $160,000 has been evaluated also and it has been concluded that the Home should be removed unless this measure is undertaken. Moreover, there would still remain the possibility of flood flows greater than those for which a reasonable degree of protection may be provided and consequently, in addition to the improved protection, consideration should be given to changing the use of the building to some other use posing less risk of loss of life.

.2 Westmount, Hillhurst, Sunnyside and Bridgeland Area

The cost of upgrading the existing dyke along the north bank of the river to make it suitable for providing protection against summer floods is estimated to be approximately $5.4 million. This cost allows for modifications to the storm sewer system which would be relocated to run parallel to the river and to discharge at a location where back-up at high river stages will not cause flooding.

The estimate assumes that the full length of dyking (4-1/4 miles) from Crowchild Bridge to St. George's Island comprises compacted fill protected by 2 feet thick rubble concrete. (Heavier riprap would be required at specific locations.) Moreover, to avoid encroachment into the river channel along Memorial Drive, expensive concrete or sheet pile retaining walls would be required at critical sections. Such walls are not included in the cost estimate. Land purchases and building relocations associated with the modifications would be likely modest as much of the land required is owned by the City and maintained in open-space use. However, many mature trees along the bank would have to be removed to accommodate the modified and realigned dyke. Also, for the dyke system to be effective along the whole reach, the low level crossing of the river under Centre Street Bridge would have to be abandoned.

The benefit of the upgraded dyke system, in terms of average annual damage prevented, would be of the order of $105,000. Since the average annual costs would be approximately $500,000, modifying the present dyke system so that it is capable of providing protection against major summer floods is not feasible on economic grounds. However, it must be stressed that the existing dykes are an integral and essential part of the works necessary to alleviate winter inundation caused by ice-packing. Consequently, even though upgrading the existing dykes to prevent summer inundation is not feasible, these dykes must be retained and maintained.

It has been suggested that, in lieu of dyke modification, Memorial Drive be raised to a level some 15 feet above a normal average low flow in the river of 3,300 cfs, i.e. raised to a level much the same as the existing dyke. From a cost standpoint, this measure would also not be feasible and it might well pose more problems than an upgraded dyke system because of access difficulties to properties fronting Memorial Drive, notably along Sunnyside.

.3 Downtown Area

As with an upgraded dyke system along the north bank, a dyke system capable of providing protection from summer floods along the south bank extending roughly from Prince's Island to the Elbow River would require fairly extensive revisions to the storm sewer system and closure of the low level crossing of the river at Centre Street Bridge. Moreover, because the present alignment of the south bank is poor and leads to a constricted river channel both upstream and downstream of Langevin Bridge, the construction of an upgraded dyke system would need to be preceded by widening of the channel. This possibility is discussed in "335 - Channel Improvements". The costs of this widening are not included in the following estimate.

On the assumption that sufficient land can be readily obtained for the construction of an upgraded dyke system rather than a retaining wall and excluding the cost of land purchase, the order of magnitude cost estimate for such a system is $2.7 million. On an annual basis, these costs would be of the order of $250,000 and clearly average annual benefits, in terms of damage prevented, of $40,000 do not justify these costs. However, there is still a need to retain and maintain the existing system to provide protection against flooding caused by winter ice packing.

In any event in this area, major reconstruction is now taking place and adequate elevations from the standpoint of flooding are being met.

.4 Pearce Estate, Inglewood Area

Nowhere else through the City of Calgary would the effects of man-made works on the passage of flood flows be as much in evidence as in the reach of river from the Elbow River downstream to below Cushing Bridge. The most important of these works from the standpoint of raising flood stages along the reach are:

- the encroachment of the south bank foreshore which began with the shortening of the South St. George's Island Bridge in the 1930's.

- the C & E Bridge with its low clearance and long approach embankment.

- the WID Dam and Cushing Bridge.

- the extensive development on the south bank flood plain adjacent to 9th Avenue S.E.

The removal of the encroachment at the South St. George's Island Bridge is recommended in "335 - Channel Improvements" as a prerequisite to further redevelopment or expansion of the zoo on the Island. Likewise, it should be a part of any scheme to provide protection to the developments on the south bank flood plain because of the rise in stage and high channel velocities that would be created by the constriction.

The provision of protection to the area would involve the following works:

- widening of the Elbow River channel below the 9th Ave. Bridge.

- dyking or landfilling between the Elbow River and 8th Street S.E. This would require the removal of some 10 properties.

- a riprapped dyke up to 10 feet high running from a point some 700 feet east of the South St. George's Island Bridge downstream to the C & E Bridge. This dyke might require the removal of two properties along New Street and from 15th Street S.E. would follow the alignment of the existing dyke fronting the concrete plant.

- widening and maintenance of the opening at the C & E Bridge to provide adequate cross-sectional area for flood flows.

- intercepting of the storm sewer outfall at 15th Street S.E.

- bank protection on the south bank downstream of Cushing Bridge.

The capital cost of these works is estimated to be approximately $1.5 million with average annual costs of $135,000. The average annual benefits in terms of damage prevented are estimated to be $65,000. Thus, while the costs exceed the benefits by a fair margin, the works would provide by far the best return on investment when compared with dyke protection against summer floods along other reaches. If sufficient support is generated by residents of the flood plain in this area, it is recommended the works should be given further consideration.

While some of the components of the works suggested might be implemented on a staged basis, the provision of protection against a designated flood would only be achieved when all components have been completed.

.5 Undeveloped Areas

As a measure for the protection of undeveloped areas, dyking may be warranted under some circumstances. The onus should be placed on the developer to demonstrate that the dykes are economically feasible and acceptable to the Province, the City and the public generally, taking into account the need for erosion protection and local drainage behind the dykes and the potential for groundwater seepage during high river stages. Where dyke protection to new developments is demonstrated to be feasible, it should be placed outside the Floodway District shown on the maps in Part 5 of this report unless compensating cross-sectional area is made available for the passage of the flood flow.

.6 Summary

With the possible exception of the Pearce Estate, Inglewood Area, upgrading the existing dykes or construction of new dykes to provide a reasonable degree of protection from summer floods to developed areas is not a feasible proposition along the Bow River. The costs of the dykes would generally be several times the benefits achieved in terms of flood damages prevented and, moreover, there could be opposition by residents of the flood plain and others because of the attendant loss of aesthetic values. In undeveloped areas of the flood plain, dykes may be warranted under certain circumstances but the onus should be placed on the developer to demonstrate their feasibility and acceptability.

Protection of future developments against a designated flood is more efficiently provided by the flood plain management concept than by the construction of dyke systems. Implementation of the concept would lead to a general raising of grade levels in the flood plain and, in the event of the

designated flood being exceeded, the depths of water on inundated areas would be modest. By comparison, once the designated flood for a dyke system is exceeded, depths of inundation on the flood plain would be the same as would occur without the dykes. In conclusion, it should be stressed that the existing dykes, while unsuitable to provide protection against summer floods, are an integral and essential part of the protective works to counteract inundation from winter ice packing. As such, they should be retained and maintained as required.

335 CHANNEL IMPROVEMENTS

Dredging of the river channel throughout the City to reduce projected flood levels is a measure which is both costly and fraught with uncertainty. For example, during the Bowness Flood Study, it was estimated that an expenditure of $1.0 million along the reach between Twin Bridges and Shouldice Bridge to remove gravel and cobbles would only bring about a reduction in average annual flood damages of some $5,000. Clearly this is an uneconomic proposition. Similar order of magnitude costs and benefits would be obtained through other reaches downstream of Bowness and detailed investigation of such measures is not warranted. Moreover, the natural armouring of the river bottom would be destroyed and it would take many years for the river to re-establish its present degree of stability.

A general widening of the river channel is similarly not a feasible proposition although there are reaches where some widening will be extremely advantageous. The Bow River, as with all rivers, tends to a specific set of dimensional parameters and man-made works to change these parameters often lead to detrimental effects. The parameters are fixed insofar as an over-wide channel leads to the deposition of large gravel bars which encourage erosion and reduce the capacity of the channel, whereas too narrow a channel leads to bank erosion and higher than desirable flood stages. However, widening of the river channel through the City is desirable along reaches where landfill activities have reduced the flood flow capacity of the river channel. Reaches where channel widening is recommended are discussed in the following paragraphs.

The benefits to be gained by minor channel improvements, such as the removal of small vegetated gravel bars, are impossible to quantify but may be substantial. It has previously been mentioned that flood damages have been calculated for idealized conditions with only a one foot allowance for extraordinary backwater effects such as would be caused by the lodgment of driftwood, brush and trees against bridges. This could lead to significantly higher water levels than estimated. In order to achieve these idealized conditions and in keeping with good maintenance practice for reaches where overbank flow could cause extensive damage, certain minor channel improvements should be undertaken. These measures would be aimed at achieving the following:

- a reduction in the resistance of the channel to flood flows which will in turn lead to a lowering of the river stage.

- the lessening of backwater effects caused by the potential lodgment of driftwood against bridges.

- the lessening of bank erosion caused by the impedance to flow offered by vegetated bars and islands which direct the flow toward the banks.

Although the reduction in river stage during flood flows may be relatively modest, it is believed that the cost of the minor improvements will be well justified by the reduced erosion potential. Improvements of this sort are fundamental in a programme of sound river and flood plain management.

.1 Bowness Reach

The most important measure recommended along this reach which extends from 85th Street Bridge to 37th Street N.W. is the channel widening being carried out in conjunction with bank stabilization below Crematorium Hill. Associated with these works are the removal of several gravel bars which will improve the hydraulic efficiency by improving the channel alignment.

In addition, works primarily involving the removal of other gravel bars and the selective removal of vegetation are also recommended at a cost of some $76,500. These are discussed in detail in the Report on the Bowness Flood Study.

.2 Westmount, Hillhurst, Sunnyside Reach

This reach of river about 4 miles along extends from 37th Street N.W. to Centre Street Bridge. The reach includes the Ice Pack Anchorage at the head of Prince's Island and any improvements planned for this reach should be cognizant of this feature as works which destroy the natural armouring of the riverbed could lead to the infilling of the Anchorage at even modest flood flows.

The channel through a major length of the reach is constricted, most notably between Crowchild Bridge and Mewata Bridge. The severest constriction occurs at 21st Street N.W. where the width at bankfull discharge is slightly over 300 feet. Removal of this constriction is the most urgent channel improvement required along the reach and it is recommended that this work be undertaken. Even with the removal of this constriction, velocities along the reach under major flood conditions will be high and could possibly lead to significant bank erosion. Protection against potential erosion along the reach would be costly. It is recommended that additional riprap be placed at this time, at the constriction only and that the reach should be monitored after major floods with a view to improving the protection elsewhere as necessary.

A summary of the works recommended along the reach together with an estimate of the costs is contained in Table 3-5. The locations of these works are shown on Plate 3-2.

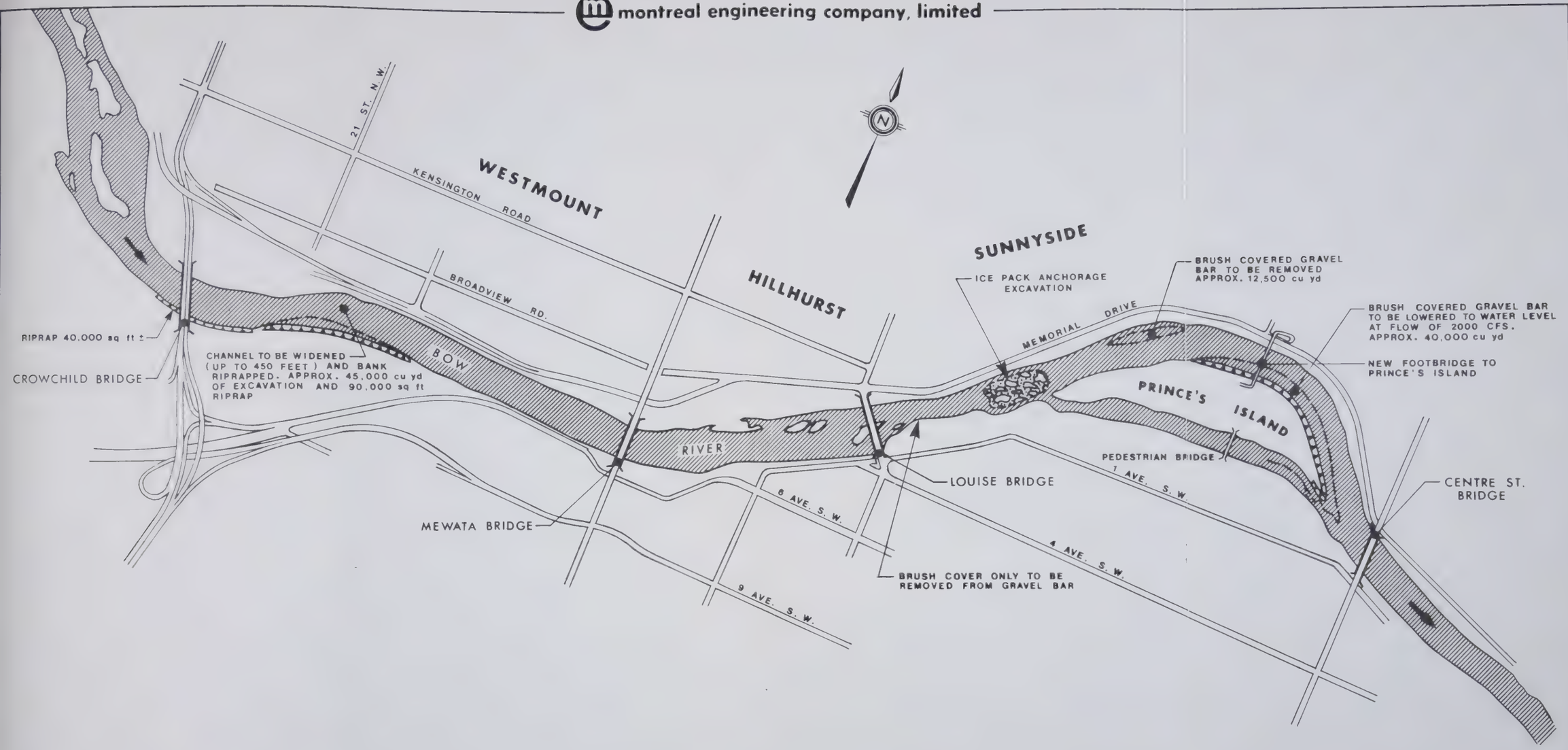

21 ST. N.W.
KENSINGTON ROAD
WESTMOUNT
BROADVIEW RD.
HILLHURST
SUNNYSIDE
ICE PACK ANCHORAGE EXCAVATION
BRUSH COVERED GRAVEL BAR TO BE REMOVED APPROX. 12,500 cu yd
MEMORIAL DRIVE
BRUSH COVERED GRAVEL BAR TO BE LOWERED TO WATER LEVEL AT FLOW OF 2000 CFS. APPROX. 40,000 cu yd
NEW FOOTBRIDGE TO PRINCE'S ISLAND
RIPRAP 40,000 sq ft ±
CROWCHILD BRIDGE
CHANNEL TO BE WIDENED (UP TO 450 FEET) AND BANK RIPRAPPED. APPROX. 45,000 cu yd OF EXCAVATION AND 90,000 sq ft RIPRAP
BOW
RIVER
PRINCE'S ISLAND
PEDESTRIAN BRIDGE
1 AVE. S.W.
LOUISE BRIDGE
CENTRE ST. BRIDGE
MEWATA BRIDGE
6 AVE. S.W.
4 AVE. S.W.
BRUSH COVER ONLY TO BE REMOVED FROM GRAVEL BAR
9 AVE. S.W.
1000 500 0 1000
SCALE 1" = 1000 FT. (Approximate)

PLATE 3-2

CHANNEL IMPROVEMENTS
WESTMOUNT, HILLHURST,
SUNNYSIDE REACH

.3 Downtown Reach

Along the Downtown reach extending from Centre Street Bridge to the Elbow River as shown on Plate 3-3, the channel is constricted by landfill and dykes on both sides of the river. The most constricted section along the reach exists immediately upstream of Langevin Bridge where the width at a flow of 50,000 cfs is only some 310 feet.

By widening the channel along the reach to a bankfull width of some 450 to 500 feet (widening taking place through the removal of material on both banks), the stage along the reach at a flow of 80,000 cfs will be lowered by as much as 2 feet. This will in turn lead to a significant decrease in potential damage in both the Downtown and Bridgeland Areas.

TABLE 3-5

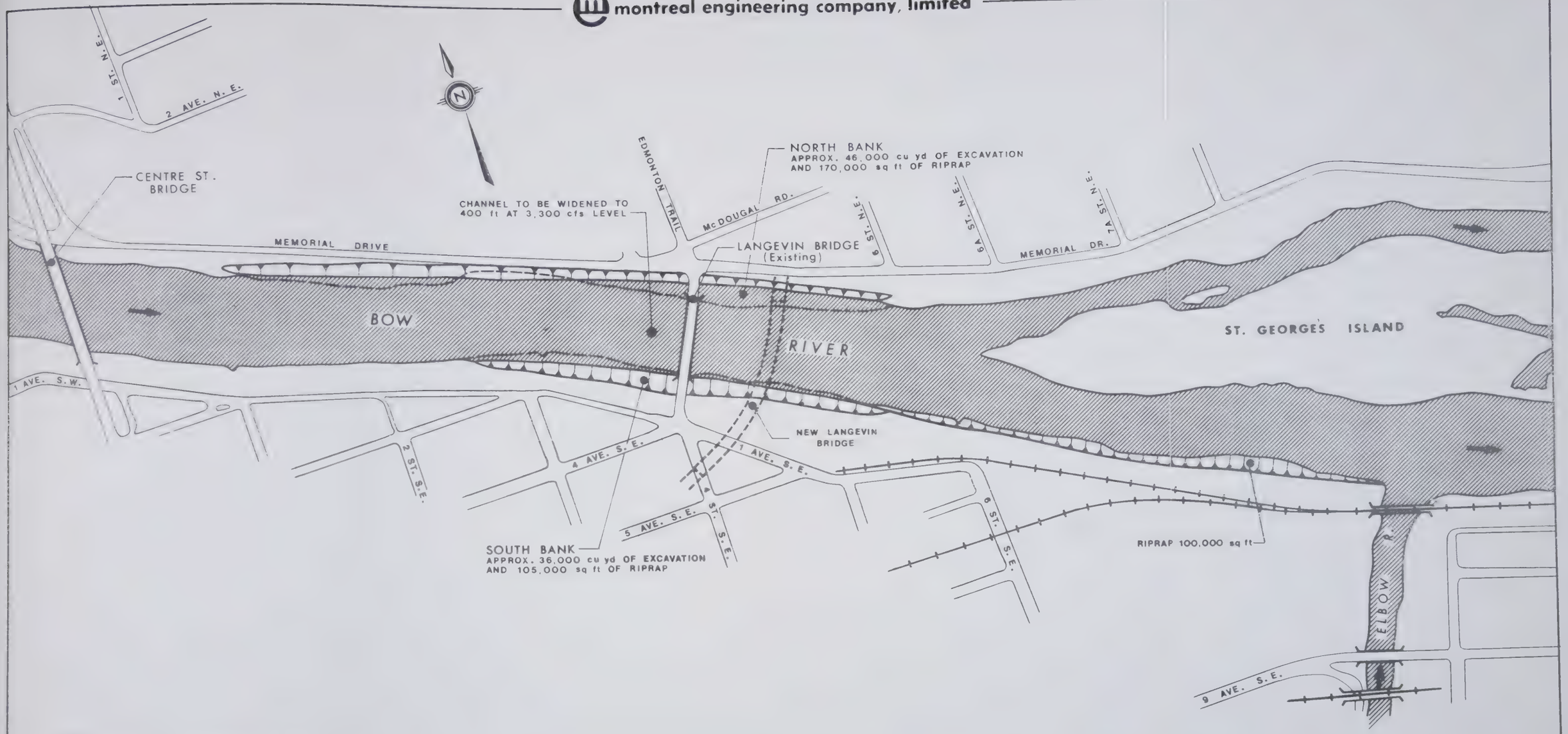
Westmount, Hillhurst, Sunnyside Channel Improvements

Item	Cost	Remarks
	$	
1. Channel widening at 21st Street, N.W.	125,000	Includes for riprap
2. Removal of gravel bar at 5A Street, N.W.	30,000	Trucked away
3. Removal of gravel bar at north side of Prince's Island	60,000	Placed on Island
4. Selective removal of vegetation	5,000	Mainly from south bank bar downstream of Louise Bridge
Total Cost	$220,000	

An order of magnitude estimate of the capital costs of the works is $340,000. It is recommended that these works be carried out as soon as it is feasible to remove the existing Langevin Bridge.

.4 St. George's Island Reach

A detailed investigation of the flow characteristics around St. George's Island was undertaken early in 1972 in response to proposals by the Calgary Zoological Society to redevelop and expand the facilities on



NOTE :

1. Works to be carried out as soon as it is feasible to remove the existing Langevin Bridge.

200 100 0 200 400 FEET

PLATE 3 – 3

CHANNEL IMPROVEMENTS
DOWNTOWN REACH

the island. The principal objective of this investigation was to determine how the Society's plans fitted into the flood plain management concept being evaluated for the City as a whole. (An earlier study, described in the St. George's Island Flood Protection Report, February 1968 evaluated various structural measures for alleviating flooding of the Island.)

With reference to Plate 3-4, the principal constrictions to the passage of the designated flood are:

- the landfill for the zoo public parking lot at the south end of the South St. George's Island Bridge;

- the landfill in the vicinity of the zoo staff parking lot on the south side of the island and east of the South St. George's Island Bridge;

- the dyke in the north channel downstream of the pedestrian bridge.

Average water levels at a designated flood of 110,000 cfs, i.e. a flood of the same order of magnitude as occurred in 1897, would be some 2 feet higher today than in the past and erosion would be substantial as a result of the constrictions and their poor alignment. It is highly likely that the South St. George's Island Bridge would be destroyed by a flood in the order of 50,000 cfs and that the pedestrian bridge over the north channel would be destroyed by a flood in the order of 40,000 cfs. From the preliminary plans, it appears that this situation would be aggravated, albeit modestly, by the redevelopment primarily proposed for the carnivora. As a result, in addition to the greater damage potential on the island itself, damage in adjacent built-up areas subject to inundation will be increased.

Where man-made encroachments on the channel and flood plain are minor, the floodway district and flood plain district are generally established without considerations of major engineering works to reduce the flood risk. The floodway district would be primarily reserved for open-space use with no further development of a structural nature permitted. Development in the flood plain district would, however, be permitted provided that it conforms to certain structural requirements. Thus, on the premise that the zoo in its present location is a permanent feature, i.e. relocation of the zoo is socially, politically and economically out of the question, it will be necessary to designate the land as flood plain district in order to permit the expansion plans and not to compromise the flood plain management concept as a whole throughout the City. Under the present circumstances where the ability of the channel and flood plain to handle the designated flood has already been severely reduced, then in keeping with similar situations elsewhere, the entire island should be designated floodway district. A change to flood plain district to enable redevelopment to proceed would require that constrictions are removed to provide compensating cross-sectional area for the designated flood.

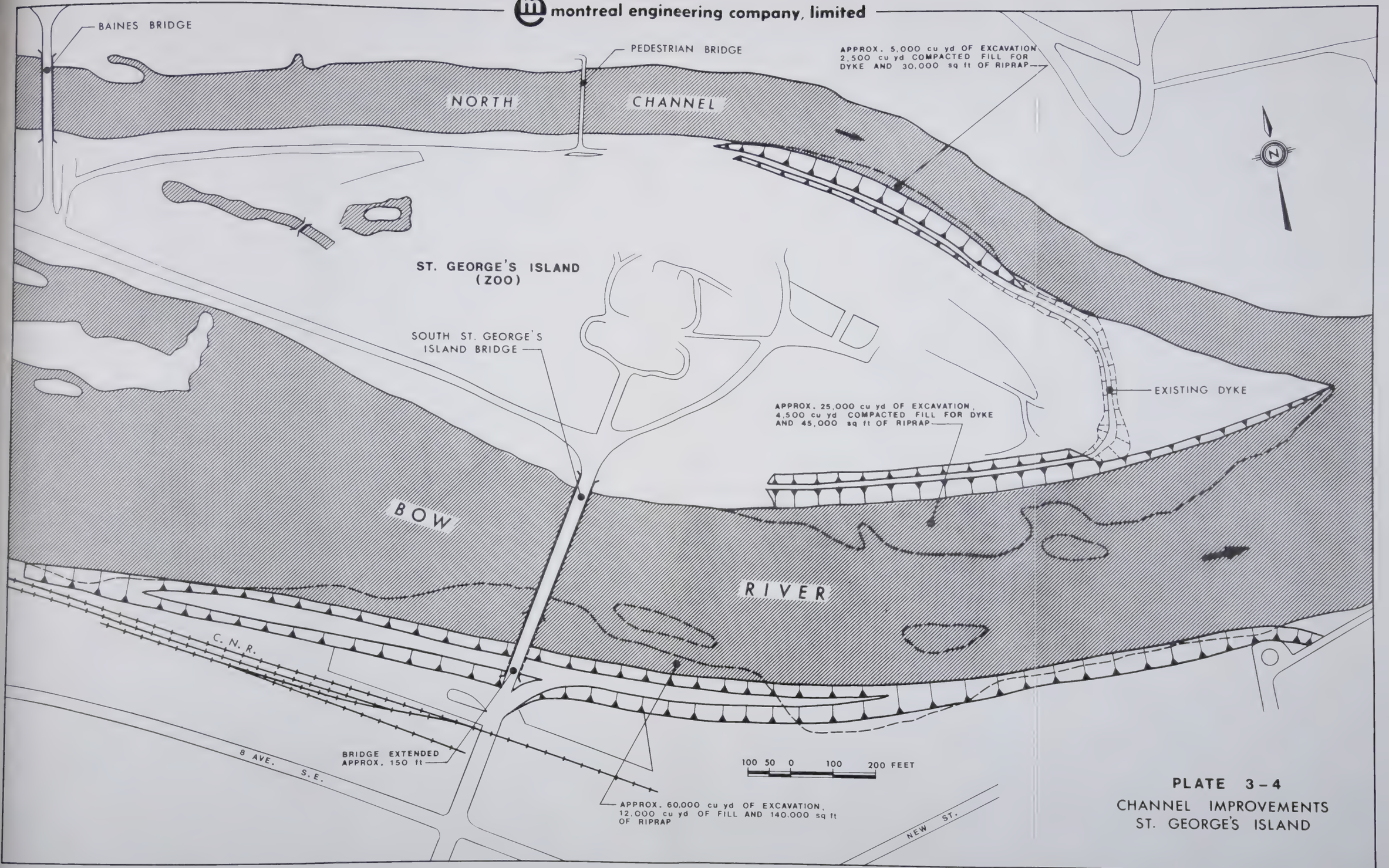


PLATE 3-4

CHANNEL IMPROVEMENTS
ST. GEORGE'S ISLAND

The cost of removing the constrictions in order to release the majority of the portion of the island occupied by the zoo for designation as a flood plain district is estimated to be $275,000. This estimate assumes that all excavated material can be conveniently used to regrade areas on the island and south shore, and would not have to be trucked substantial distances. The cost includes for riprap of regraded slopes with a 2-ft thickness of rubble concrete which may be placed as and when suitable quantities become available, and for administration, contingencies and engineering.

A separate estimate produced by the City of Calgary Engineering Department, Maintenance Division, indicates that the cost of extending the present bridge by some 150 ft (from 350 to 500 ft) will be approximately $65,000 for a three-span, precast concrete structure with poured in place piers. It should, however, be noted that the extended bridge will still not withstand the passage of the designated flood of 110,000 cfs. With the improved cross-section, the underside elevation of the truss section of the bridge would be some 1 to 2 ft below the flood stage and severe erosion leading to failure of the north abutment could be anticipated well before this stage is reached.

It must be stressed that the recommended works are in keeping with the ultimate concept for the rehabilitation of this whole reach of river presented in the 1969 report on St. George's Island. They do not, however, afford complete protection to either the island or adjacent flood plains; rather they will reduce the severity of flooding in terms of lowering water levels and lessening erosion through a better channel alignment and riprap protection. The possibility of providing protection to the adjacent south bank flood plain has been discussed in "334 - Dykes".

Thus, it is recommended that the channel widening works be carried out as a prerequisite to further development or expansion of the zoo facilities on St. George's Island and, at the time of writing this report, a firm commitment for carrying out the works has been made. Under these circumstances, redevelopment of the zoo facilities may generally proceed at the locations indicated on preliminary plans. However, the free range area for the cats, lions and tigers may have to be slightly reduced in order to accommodate the north channel widening and it is recommended that the new building for birds planned for the low-lying land in the southeast corner of the island be relocated so as to fall within the Flood Plain District. Moreover, any structures presently outside the area should be relocated at the earliest opportunity. Notable amongst these are the house and garage at the north end of the South St. George's Island Bridge and the birds of prey cage also on the southeast corner of the island.

.5 Pearce Estate, Inglewood Reach

Along the reach from the C & E Bridge downstream to Bonnybrook Bridge, the hydraulic efficiency of the channel is impaired by landfill encroachments and several brush-covered gravel bars. The encroachments cause high channel velocities and the bars deflect the current into

generally ill-defined and unprotected banks. Consequently, there would be severe erosion under major flood conditions.

The worst constriction to flow takes place some 100 feet downstream of Cushing Bridge, this being caused partly by landfill on the west bank and partly by private dyking on the east bank. Moreover, the abandoned piers of the old Cushing Bridge also inhibit the passage of flood flows. Erosion effects would be greater in the vicinity of the Bridge because of the proximity of development on the right bank and, with reference to Plate 3-5, it is recommended that channel improvements along the reach be concentrated in the vicinity of the Bridge.

Thus, the works necessary to improve the flow characteristics are as follows:

- widening and realignment of the channel downstream of Cushing Bridge to a width at least that of the bridge opening. This will involve the removal of material and regrading of banks on both sides of the channel.

- removal of the piers of the former Cushing Bridge.

- removal of the brush-covered bar some 2,000 feet downstream of the bridge to a level slightly below that of a flow of 2,000 cfs.

- riprap protection to the west bank only for a length of some 3,000 feet downstream of the bridge.

The cost of undertaking these works is estimated at $200,000 and it is recommended that they be carried out.

Constrictions and bars other than those recommended for removal would also cause detrimental effects under major flood conditions. However, because of the general lack of development along the reach, it is not recommended that further improvements be carried out at this time. Rather, the situation should be reviewed prior to further development or subsequent to a major flood.

.6 Summary

Channel improvements (excluding those along the Bowness reach) costing in total some $1,035,000 have been recommended for implementation. With the exception of the channel widening along the Downtown reach which should be carried out at such time as the existing Langevin Bridge is replaced, all the improvements are recommended for implementation at the earliest opportunity.

The recommended district maps produced in Part 5 of this report assume that the channel improvements recommended will be implemented. Otherwise, the extents of the Floodway and Flood Plain Districts, as well as the step limit elevations, would be appreciably greater.

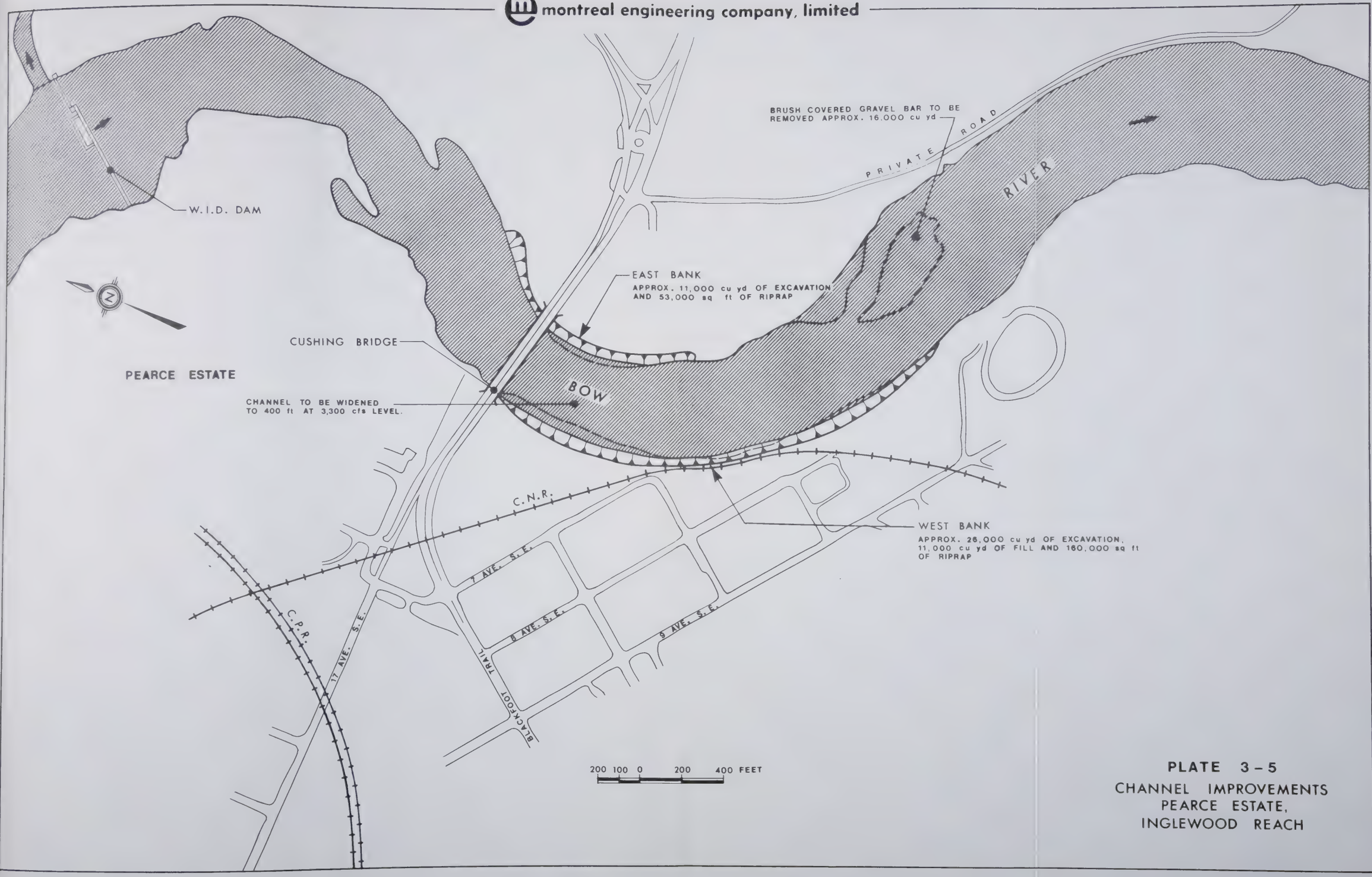

BRUSH COVERED GRAVEL BAR TO BE REMOVED APPROX. 16,000 cu yd
PRIVATE ROAD
RIVER
W.I.D. DAM
EAST BANK
APPROX. 11,000 cu yd OF EXCAVATION AND 53,000 sq ft OF RIPRAP
CUSHING BRIDGE
PEARCE ESTATE
CHANNEL TO BE WIDENED TO 400 ft AT 3,300 cfs LEVEL.
BOW
C.N.R.
WEST BANK
APPROX. 26,000 cu yd OF EXCAVATION, 11,000 cu yd OF FILL AND 160,000 sq ft OF RIPRAP
7 AVE. S.E.
8 AVE. S.E.
9 AVE. S.E.
17 AVE. S.E.
C.P.R.
BLACKFOOT TRAIL
200 100 0 200 400 FEET

PLATE 3 – 5

CHANNEL IMPROVEMENTS
PEARCE ESTATE,
INGLEWOOD REACH

Efforts and expenditures on channel improvements should be concentrated along reaches where development has already proceeded. For this reason, no improvements are recommended at this time for the reach below Bonnybrook Bridge. Along undeveloped reaches the situation should be reviewed prior to development or subsequent to a major flood. With the implementation of the flood plain management concept, landfill and other encroachments into the channel will be precluded and development will be set back from the main channel of the river so that the need for improvements of the type outlined will be greatly reduced.

336 BANK STABILIZATION

The catastrophic situation that would result at times of a major flood flow from the rapid failure of the unstable bank below Crematorium Hill is discussed in the report on the Bowness Flood Study. Recommendations for stabilizing the slope are contained therein and are currently being implemented.

The next most critical slide area identified along the Bowness Study Reach is on the south bank of the river below Wildwood Drive. This area represents potential earth movements in excess of 700,000 cubic yards which seriously threaten the railway line and could encroach on the river channel. It is recommended that this area be investigated in detail and monitored by slope indicators and piezometers.

In total, 32 different slide areas have been identified along the Bowness Study Reach, but excepting the areas previously discussed, these are generally of minor importance as far as potential encroachment on the river channel is concerned. It is, however, recommended that the potential slide area identified opposite Shouldice Park (potentially the largest) be monitored and that a continuous check be made on the undercutting and erosion which is taking place at several locations along the study reach.

Along the remainder of the Bow River through the City, other active slide areas which might be affected by major flood flows have been identified. They are located along the undeveloped reach below Bonnybrook Bridge. The two most important areas are the west bank and east bank respectively some 1/2 mile and 2-1/2 miles downstream of Gallelli's Bridge. These should be investigated in some detail prior to development on adjacent flood plains or subsequent to the passage of a flood, particularly if erosion of the toe of the potential slide is significant.

337 GRAVEL OPERATIONS

The main gravel mining areas adjacent to the Bow River are located in the southeast quadrant of the City, principally in the Barlow Sector on the east bank of the river downstream of Graves (Glenmore Trail) Bridge. Most existing and planned operations in this area are outside of the flood plain and are currently the subject of a separate study which is evaluating such factors as the cost of land reclamation upon cessation of the mining and the effects of the operations on groundwater conditions.

The preliminary plans of the operators call, in certain areas, for mining to take place close to the river's edge. It is important to ensure that mining of gravel does not lead to a major alteration in channel stability as changes of this nature are likely to occur at time of flood flow. For example, the formation of an overwide river through mining along the banks will lead to the deposition of unnatural gravel bars which will in turn encourage the erosion of adjacent banks at times of flood flows. Moreover, if substantial quantities of consolidated material are removed from the banks and flood plain below the normal groundwater table, the probability of major shifts in the channel alignment, with the attendant problems this poses, is increased. These effects are not readily perceived and the principal purpose of this section of the report is to propose minimum safeguards for the mining of gravel close to the river. These safeguards are meant to ensure that the river maintains its present course during a major flood and that bank erosion to properties adjacent or downstream of the proposed operations is not increased.

Using the district maps as a guide, it is recommended that:

(1) No mining for gravel or the stock piling of material be carried out in the Floodway District unless specifically designated for the improvement of the channel efficiency.

(2) Subject to other regulations not pertinent to potential flooding, mining be permitted in the Flood Plain District provided that:-

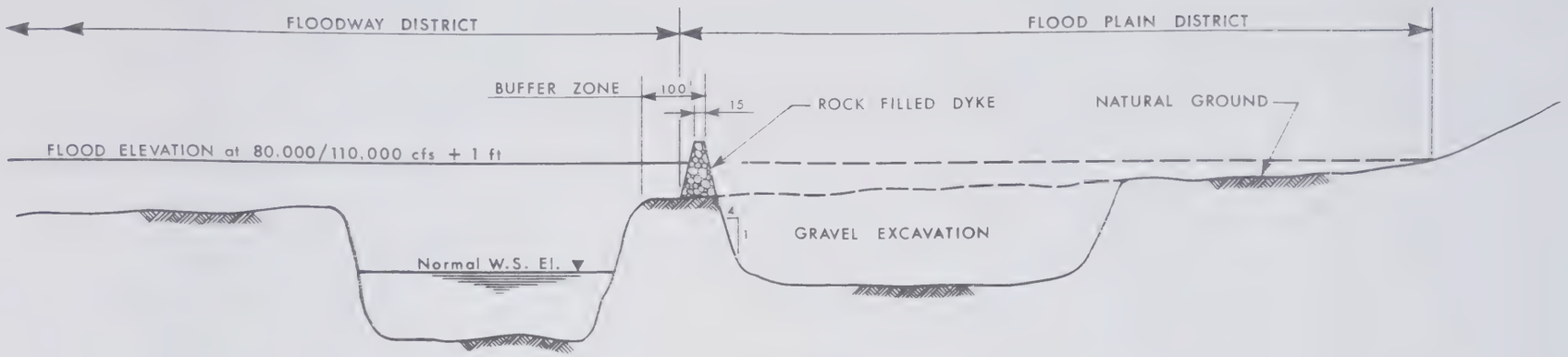
- a buffer zone of undisturbed material with a minimum width of 100 feet be left between the river's edge and the mining operations.

- a stable dyke comprising cobbles or riprap be built along the buffer zone to an elevation compatible with the step limit elevations shown on the zoning maps. This will prevent the direct overflow of flood waters into the operations.

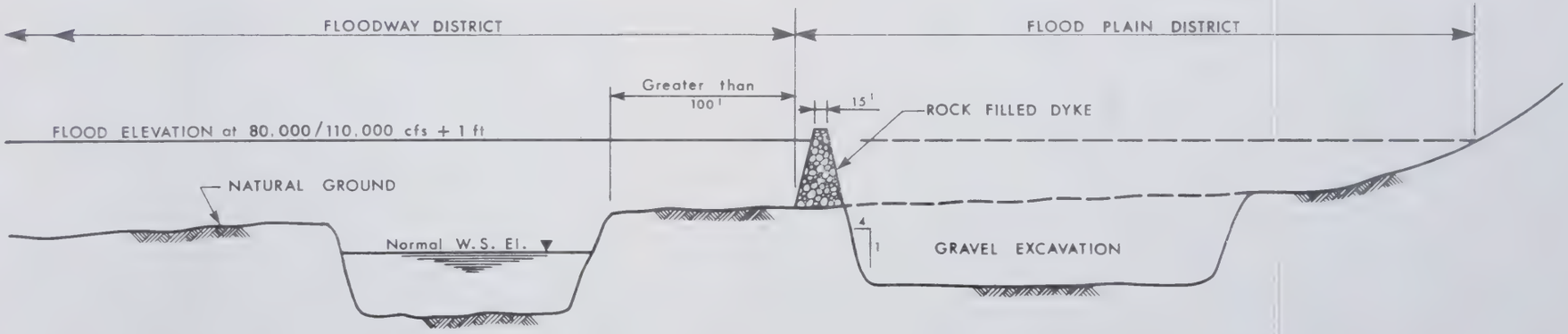
These recommendations are illustrated in Plate 3-6.

338 BRIDGE WATERWAYS

Bridges must be designed with adequate section to pass flood flows. Unduly confining flood waters at bridges can cause excessive backwater resulting in significantly increased flooding to upstream property, overtopping of roadways and excessive scour under the bridge leading to costly maintenance or even loss of the bridge. On the other hand, making bridges longer than necessary for the sake of safety can add materially to the initial cost, especially when multiple lane bridges are involved. Somewhere between the two extremes is the bridge which will prove not only safe but the most economical to the public over a long period of time.



(a) BUFFER ZONE WIDER THAN FLOODWAY DISTRICT



(b) FLOODWAY DISTRICT WIDER THAN BUFFER ZONE

PLATE 3-6

RECOMMENDED PRACTICE
FOR GRAVEL OPERATIONS

For the Bow River through Calgary, it is recommended that all future bridges of a permanent nature be adequate to pass the designated flood used for the establishment of the flood plain management concept, i.e. 80,000 and 110,000 cfs upstream and downstream of the Elbow River respectively. The type of bridge that will be adequate to pass these flows will vary from section to section along the river and the following are the main factors to be considered in the designs:

(i) the relative amounts of flow expected in the channel and overbanks at the designated flood. In general, the greater the percentage of flow through the flood plain, the wider is the overall bridge opening required.

(ii) the importance of the bridge as a transportation route during floods. For example, if it is essential to maintain the bridge in service during a flood, approach embankments across the flood plain should be elevated above anticipated water levels. This would cut off flow relief through the flood plain and increase backwater thus necessitating a wider bridge to compensate for the backwater. On the other hand, if flow relief is permissible through the overtopping of approach embankments, then a narrower bridge opening may be used.

(iii) the opening should be such as to produce a maximum backwater of 1 foot, the calculation being carried out under the assumption of a fixed channel bed.

It should be noted that bridges across the Bow River built to the width of the Floodway District and with low chord elevation some 4 feet above the step-limit elevation (sufficient to avoid the trapping of debris) will be adequate to pass the designated flood. Thus, at most sections along the river, especially above the Elbow River, bridges with a top net width of some 500 to 550 feet at right angles to the flow and with a minimum low chord elevation some 20 feet above normal water level at a flow of 3,300 cfs should generally be sufficient.

The existing bridges are discussed in detail in Appendix B of the 1968 report entitled 'Flood Plain of the Bow River in the City of Calgary'. While several of these are capable of passing the designated flood without suffering major damage and causing significant backwater, only a limited number would remain in service at the peak of the flood. Most notable of these are the 85th Street Bridge (provided abutment erosion which may be severe does not endanger the bridge), Trans-Canada Highway Bridge and the Crowchild Trail Bridge (assuming adequate erosion protection of the right abutment, see Plate 3-2), all three being on the western side of the City. All other road bridges would be cut off as a result of the inundation of approach roads.

Consequently, it is believed there is a pressing need to provide more bridges which will remain in operation, especially along the Downtown reach.

The most advantageous location to achieve this is at Centre Street Bridge. It is recommended that plans in this area include for the raising of the grade level of Centre Street at the south side of the bridge by up to 2 feet as far south as 3rd Avenue. Similarly, it is recommended that, if possible, the new bridge crossing of the river required for the south extension of the Blackfoot Trail (specific location unknown) be designed to remain in service during the passage of the designated flood.

Of the existing bridges, specific mention should be made of the C & E Bridge downstream of St. George's Island as plans for shortening the overbank portion of this bridge have been proposed. The plans call for the replacement of existing side spans with fill reducing the net width normal to flow from some 550 to 435 feet. Under present conditions, the bridge and its long approach embankment across the low flood plain give rise to a backwater immediately upstream of some 2 feet. In view of the intensive development upstream, no works which would further increase the upstream stage, however modestly, should be allowed. Thus, it is recommended that filling of the side spans of the C & E Bridge not be permitted.

Two other bridges which could cause detrimental effects are the private bridges with low clearance downstream of Graves Bridge. Both will probably be destroyed prior to the arrival of a 50,000 cfs flood and their removal should be a prerequisite to any development on adjacent banks.

339 ICE PACK ANCHORAGE

The Ice Pack Anchorage at the head of Prince's Island comprises an excavation in the main channel of the river which was first constructed in 1959 and further extended in 1963. In total, some 150,000 cubic yards of material were removed and placed along the right bank of the river downstream of Louise Bridge and on the east part of Prince's Island Park.

The purpose of the excavation is to trap slush ice, which results in the formation of an ice bridge. This in turn thickens into a hanging dam at an optimum location along the river and reduces the likelihood of the movements which could cause blockage and hence flooding.

The efficiency of the Ice Pack Anchorage, with its deep excavation, is contingent upon other factors. These consist of the vegetated, right-bank gravel bar downstream of Louise Bridge and the massive piers of the bridge which aid in retarding ice pack movements.

It is recommended, therefore, that the existing conformation of the channel in the vicinity of Louise Bridge be generally maintained in the planning of the new bridge.

3310 STRUCTURAL ADJUSTMENTS TO INDIVIDUAL PROPERTIES

The costs and benefits of carrying out structural adjustments to individual properties were analyzed in the report on the Bowness Flood Study. The analysis was principally concerned with underpinning and anchoring to prevent houses being washed away or lifted off their foundations and also with the elevation of buildings on their existing block or concrete-walled basements.

The analysis demonstrated that structural changes to individual properties can offer only modest opportunities for damage reduction in the Bowness Area. The situation in Bowness would be reflected throughout the City. However, the analysis was carried out on an overall basis and it is possible that, whereas in aggregate these adjustments do not appear economically feasible, there may be individual properties where adjustments of this sort would be warranted. Nevertheless, the number of these throughout the City would likely be small and certainly insufficient to justify the problems of establishing a suitable programme of financial assistance.

PART 4 - RECOMMENDED PLAN

CONTENTS

		PAGE
4.1	STRATEGY	4-2
4.2	COURSE OF ACTION	4-4

The optimum combination of measures to deal with the potential flood hazard along the Bow River through the City of Calgary will comprise a mixture of small-scale corrective measures providing some degree of protection together with administrative measures to manage development in the flood plain, and in the long term, bring about a large-scale reduction in the potential economic loss and hardship.

From the analysis presented in Parts 2 and 3, it is concluded that large-scale corrective measures involving major engineering works to alleviate the hazard cannot be justified on economic grounds. Moreover, even if economic feasibility were not the main criterion, some of the major engineering measures, e.g. new dyking, might meet with so much local opposition that their implementation under present conditions would be impeded if not precluded.

The flood potential through the City does not presently warrant the vast expenditures of public money required to provide protection against a flood of magnitude similar to that which occurred in 1897. However, the situation is serious enough to require positive action especially as only approximately 21 per cent of the flood plain land through the City has been intensively developed. Investment in this land appears to be on an upward trend and pressures to develop other flood plain lands are apparent.

The following section describes the strategy which has emerged and which should be implemented without delay. The elements of this strategy have been chosen so as to achieve the objectives enumerated at the beginning of Part 3 in an optimal manner. The objectives are:

(1) To minimize the risk of a flood disaster in terms of death and extensive property damage.

(2) To ensure that the costs associated with minimizing the flood risk to new developments in the flood plain are borne by the beneficiaries, i.e. the land and property owners, and not the public at large.

(3) To prevent potentially high maintenance costs resulting from channel erosion.

(4) To preserve and improve the aesthetic characteristics of the valley bottom.

(5) To minimize the area of valley bottom lands which must be reserved for passage of flood waters.

The concluding section of the report recommends the course of action to be followed in implementing the strategy.

4.1 STRATEGY

It is recommended that the appropriate strategy or plan for minimizing potential economic loss and hardship from floods along the Bow River comprise the following elements listed in the order in which they are discussed in the body of this report.

1. The adoption of statutory guidelines for controlling development in the flood plain. In particular, two districts, namely the Floodway District and Flood Plain District, should be established. The guidelines would ensure that, in general, no further development be permitted in the high risk Floodway District encompassing the main channel of the river. New development would be permitted in the Flood Plain District, as determined by local bylaws, provided that it conforms with building standards embodied in the guidelines. The recommended boundaries of the Floodway District and Flood Plain District together with accompanying guidelines, are presented in Part 5.

2. The establishment of a flood forecasting centre by a federal or provincial agency together with clearly defined procedures for issuing flood warnings by the City and the installation and operation at the centre of a computerized watershed model linked to a network of continuously or frequently reporting meteorological and streamflow gauges. Such a system will:

   - permit earlier advanced warning of the impending flood in the City of Calgary and, thereby, facilitate emergency action.

   - assist in the operation of Ghost Reservoir to reduce the flood peak without compromising the need to refill the storage so that power production, statutory irrigation releases and recreational uses are not detrimentally affected.

3. Engineering measures to improve the hydraulic efficiency of the channel, reduce potential bank erosion and bring about modest reductions in flood stage. In general, the improvements recommended involve the removal of constrictions. The Recommended District maps in Part 5 show the locations of the measures and are produced on the assumption that the measures will be implemented in the relatively near future. Otherwise, the maps will require alterations to show higher step limit elevations and greater extents of the Flood Plain District upstream of the constrictions. The improvements are listed in the order of priority in which they should be carried out:

   - at the bend in the river upstream of Shouldice Bridge below Crematorium Hill. Rehabilitation of the channel, including widening and realignment, is currently being undertaken in conjunction with the stabilization of the active slide area.

- in the vicinity of St. George's Island. The primary requirement is for the removal of landfill into the channel at the south side of the South St. George's Island Bridge. In February 1972, the City Council, in authorizing further development of the zoo, made a firm commitment to carry out the works recommended not later than 1973.

- upstream and downstream of the old Langevin Bridge. Removal of material from both banks is required.

- downstream of Crowchild Bridge. Removal of material from the right bank is required to improve the cross-section and channel alignment.

- downstream of Cushing Bridge. Removal of material from both left and right banks is required.

4. A public information programme. Such a programme will be an essential first step towards gaining public acceptance of this strategy and, in particular, the adoption of statutory guidelines. Moreover, such a programme can encourage adjustments which individual and corporate property owners may take ahead of and at the time of flooding e.g. evacuation, flood-proofing, elevation of structures and movable items, etc.

In addition to the principal elements listed, there are three priority areas (in order of priority) along the Bowness reach of the river where the following measures should be undertaken:

- Bow Bend Trailer Court Park on the inside of the bend downstream of the No. 1 Highway Bridge. Potential loss of life here is acute due to the danger of the trailers being picked up and swept downstream. Also of great importance is the likelihood of the trailers causing blockage at bridges. Removal and relocation of the trailers at an early date is recommended.

- Bow View Nursing Home where dyking to provide a reasonable degree of flood protection would cost in the region of $160,000. Even with this protection, it is recommended that consideration be given to changing the use of the building to some other use posing less risk of loss of life.

- The five properties on Bowbank Crescent falling in the Floodway District. Removal or relocation of these properties appears to be necessary and a way to do this to the satisfaction of the owners will have to be devised, recognizing that it may be necessary to wait until the properties come on the market.

Along the remainder of the river, with the possible exception of the east part of Sunnyside and the mobile home park at the junction of the Blackfoot Trail and Highway No. 1A, which it is understood may be relocated at the

same time as the proposed extensions to the Blackfoot Trail, there are no residential structures as vulnerable to summer floods as those along the Bowness reach.

Of other measures which might be included in the strategy, a dyke scheme for protecting most of the Pearce Estate, Inglewood Area is the best of the various possibilities which have been evaluated. While the costs of the scheme exceed the benefits in terms of reduced flood damages by a substantial margin, it should be given further consideration if the residents and occupants of the flood plain in the area support it. If this scheme is implemented, appropriate modifications to controls over development in the flood plain will be needed.

In summary, it is stressed that by far the most important element of the strategy is the adoption of the statutory guidelines. This measure will play the key role in minimizing potential damages and hardships due to flooding in the City of Calgary, particularly in the long term. The other recommended measures are complementary to the firm management of developments in the flood plain. It is believed, when viewed from an overall standpoint, the recommended measures offer a comprehensive and balanced plan to deal with the flood hazard.

4.2 COURSE OF ACTION

The successful implementation of each of the elements of the recommended plan will depend largely upon the extent to which the public recognizes their value in reducing potential damage and hardship. Since the principal element involves management of developments in the flood plain, many more persons will be directly affected than would be the case if the plan were based on the construction of major engineering works such as dams, floodways and dykes.

In view of the concerns expressed in the written submissions and verbal presentations on the Bowness Flood Study to the Standing Policy Committee on Operations and Development, it is suggested that the following course of action comprising three basic steps be pursued:

Step 1 A letter be distributed to every resident or manager of property in the flood plain. This letter would briefly summarize the recommended plan and clearly explain why the various elements have been recommended. The letter should indicate that flood plain maps and guidelines are available upon request and should invite recipients to communicate their reaction to the leaders of community associations in the flood plain and to the City administration.

Step 2 A suitable time after distribution of the letters, discussions be held with the leaders of community associations, developers, etc. to ascertain their reaction to the plan. Particular emphasis

should be placed on the adoption of statutory guidelines for controlling development in the flood plain.

Step 3 A series of public information meetings be held at which any suggested changes to details of the plan would be discussed and any further submissions or outstanding questions would be aired and hopefully resolved.

In this way, many questions and objections of the sort made at the public hearing on the Bowness Flood Study could be resolved in a rational manner and might obviate the need for a formal public hearing. In any event, every effort should be expended to gain public acceptance of and confidence in the plan and, thereby, give both the Province and the City a clear mandate to proceed immediately with its implementation.

PART 5 - GUIDELINES AND MAPS SHOWING FLOODWAY AND FLOOD PLAIN DISTRICTS

CONTENTS

		PAGE
5.1	INTRODUCTION	5-1
5.2	PURPOSE	5-1
5.3	PROCEDURE	5-2
	531 FLOODWAY DISTRICT	5-2
	532 FLOOD PLAIN DISTRICT	5-3
5.4	DISTRICT BOUNDARY ALTERATIONS	5-4

PLATES

PLATE		
5-1	Location of Maps Showing Recommended Floodway and Flood Plain Districts Along Bow River.	5-5
5-2	85th St. N.W. to 69th St. N.W.	5-6
5-3	69th St. N.W. to Shouldice Bridge	5-7
5-4	Shouldice Bridge to 16th Ave. N.W.	5-8
5-5	16th Ave. N.W. to 37th St. N.W.	5-9
5-6	37th St. N.W. to 24th St. S.W.	5-10
5-7	24th St. S.W. to Mewata Bridge	5-11
5-8	Mewata Bridge to 4th St. N.W.	5-12
5-9	4th St. S.W. to 6th St. S.E.	5-13
5-10	6th St. S.E. to 15th St. S.E.	5-14

PLATE		PAGE
5-11	15th St. S.E. to Cushing Bridge - Left Bank	5-15
5-12	15th St. S.E. to Cushing Bridge - Right Bank	5-16
5-13	17th Ave. S.E. to 32nd Ave. S.E.	5-17
5-14	32nd Ave. S.E. to 46th Ave. S.E.	5-18
5-15	46th Ave. S.E. to 64th Ave. S.E.	5-19
5-16	64th Ave. S.E. to 80th Ave. S.E. - Left Bank	5-20
5-17	64th Ave. S.E. to 80th Ave. S.E. - Right Bank	5-21
5-18	80th Ave. S.E. to 96th Ave. S.E. - Left Bank	5-22
5-19	80th Ave. S.E. to 96th Ave. S.E. - Right Bank	5-23
5-20	96th Ave. S.E. to 114th Ave. S.E. - Left Bank	5-24
5-21	96th Ave. S.E. to 114th Ave. S.E. - Right Bank	5-25
5-22	114th Ave. S.E. to 130th Ave. S.E.	5-26
5-23	130th Ave. S.E. to 142nd Ave. S.E. - Left Bank	5-27
5-24	130th Ave. S.E. to 142nd Ave. S.E. - Right Bank	5-28
5-25	142nd Ave. S.E. to 158th Ave. S.E. - Left Bank	5-29
5-26	142nd Ave. S.E. to 158th Ave. S.E. - Right Bank	5-30
5-27	158th Ave. S.E. to Fish Creek	5-31

5.1 INTRODUCTION

The proposed guidelines and maps contained in this part of the report have been drawn up for the two district concept of flood plain management as previously described. The two districts are called respectively the Floodway District and Flood Plain District.

In brief, the Floodway District would encompass the channel and a strip of land along both banks. There are presently few structures in this district and no further development which would impede the passage of a major flood would be permitted in the district.

The Flood Plain District would extend from the Floodway District to the limit of inundation of the designated flood. Contingent upon factors other than the flood hazard (for example, the need for parkland or transportational facilities), development might be permitted in the Flood Plain District provided that it meets standards of a mainly structural nature. The standards would apply principally to new developments.

It should be noted that the guidelines and accompanying district maps do not in themselves establish a land-use plan for valley bottom lands. Instead, they form one of the several inputs which have to be considered when a preferred land-use plan is drawn up.

The following paragraphs explain in greater detail the purpose of the proposed guidelines and the standards that might be applied in a consistent manner to the lands throughout the City of Calgary which are subject to the flood hazard.

5.2 PURPOSE

The purpose of creating two special districts in the flood plain would be twofold as follows:

- to protect public health and to minimize the danger of life and property which results from development undertaken without full realization of such danger;

- to lessen the potential flood damages and financial burdens imposed upon the community by rescue and relief efforts occasioned by the occupancy of such flood areas.

5.3 PROCEDURE

Guidelines or statutory controls to regulate flood plain use and development are generally drafted in a form which consists of three basic parts. These are the text, the schedules of districts regulations and the official zoning maps. The "text" should contain the administrative procedures for adopting, enforcing and amending the guidelines. The "schedule of district regulations" should contain the specific development standards and requirements for each of the districts established and the "official zoning maps" should delineate the boundary of each district. It is in these latter two sections that provisions for flood plain protection and control should be incorporated. On the basis of the two district concept, these two sections would set encroachment limits for the Floodway District in order to ensure an unobstructed flow of flood waters and establish limits and elevations within which construction can be allowed in the Flood Plain District.

531 FLOODWAY DISTRICT

The Floodway District is defined as the present channel plus those portions of land which are needed to convey a flood of designated magnitude without unreasonably raising the upstream water levels above the natural levels that would exist if the channel were well maintained.

For the establishment of this district through the City of Calgary, it is recommended that the designated flood be 80,000 cubic feet per second for the Bow River upstream of the confluence with the Elbow River, 110,000 cubic feet per second downstream of the confluence with the Elbow River and 15,000 cubic feet per second for Fish Creek. The designated flood for other streams in Calgary, such as the Elbow River and Nose Creek, would be determined after suitable hydrologic investigations.

Because of the extreme hazard posed to land in the Floodway District, it is recommended that the use of land in the district be limited to the following:

- agricultural activities in the nature of farming, grazing, livestock raising, horticulture and nurseries;

- recreational activities in the nature of parks, playgrounds, golf courses, and such transient amusement enterprises as circuses, rides or shows, or any similar open use;

- uses and related structures whose presence will not significantly block the flood channel but whose nature requires location in the Floodway District because of:

  (a) liquid waste disposal, surface drainage, such as sewer outfalls, or

  (b) transportation facilities not available elsewhere.

- other uses of land or a structure similar in character and purpose.

In addition, it is recommended that guidelines to control development be drafted in a form so as to prohibit specifically any major structures or any land use which adversely affects the efficiency of or unduly restricts the capacity of the Floodway District to pass a flood. For example, the guidelines might prohibit the filling of the floodway with dirt, gravel, minerals, or other types of waste material commonly termed as junk, trash, garbage or offal.

Implementation of the guidelines for the Floodway District would result in several uses and buildings becoming non-conforming although the scope of this problem through the City and particularly along Fish Creek is not of major significance.

532 FLOOD PLAIN DISTRICT

The Flood Plain District is defined as the additional portions of land over and above the Floodway District not needed for the conveyance of the designated flood but which are, nonetheless, subject to inundation. It is the geographic area between the boundary of the Floodway District and the limit of inundation by a flood of designated magnitude with an allowance of one foot for backwater effects. The same designated flood is used for the establishment of the Flood Plain District as for the Floodway District.

Land use and building in the Flood Plain District would be determined primarily by the development plan for the whole City except that the following uses would be prohibited:

- institutions or places of assembly for the mentally or physically ill or the young; senior citizens homes or nursing homes, places of incarceration and schools. This would be necessary because of the special problems posed if evacuation were required.

- mobile home parks and holiday trailer parks. This would be necessary because of the danger of the types of structures associated with the parks being carried away by flood waters and causing further damage.

- the open storage of equipment, material and goods (other than those which can be removed readily or would not float away) below the step limit elevations on the proposed district maps. This would be necessary because of the deleterious effects which can result from these entering the main watercourse.

All other uses would be permitted except that buildings will need to be designed to structural standards so that they would suffer minimal damage during flood conditions. The standards might, for example, require the following differences from conventionally designed buildings outside the Flood Plain District:

- all principal electrical, heating or mechanical services should be at or above the step limit elevation shown on the proposed district maps.

- buildings be elevated on suitably designed piles or columns such that all floors, equipment rooms and closed areas are above the step limit elevations indicated on the proposed district maps and, where shown necessary by engineering studies, be anchored to resist flotation and lateral movement.

- buildings have their first floor level, whether basement, cellar or otherwise, constructed at or above the step limit elevation for the particular area shown on the proposed district maps by raising the ground level with fill to achieve this elevation. If this form of construction is preferred, it is recommended that the fill extend at least 15 feet beyond the limits of any building erected thereon.

Where it is desirable to have a building with a basement or cellar floor below the step limit elevation, this floor should not be used for human habitation. Moreover, the standards should be drafted to ensure that the building is:

- anchored to resist flotation and lateral movement;

- constructed to withstand rupture and collapse from the hydrostatic pressures of an elevated watertable through the use of reinforced walls and floors, and pumping facilities to relieve pressures;

- watertight through the use of paints, membranes and mortars to reduce seepage, the use of pumping facilities, and the installation of cutoff valves on sewer lines or the elimination of gravity flow basement drains.

5.4 DISTRICT BOUNDARY ALTERATIONS

The boundaries of the proposed Floodway and Flood Plain Districts along the Bow River are shown on the maps which follow. The boundaries of the districts have been established using the best information available at this time but changes in the delineation of the districts may be made if the person requesting the change can prove that:

- a flood control project of the federal, province or city government or of a private person will alter or has altered the flood hazards, or

- flood data compiled subsequent to the implementation of the guidelines indicate that the district boundaries as shown on the maps have been located incorrectly.

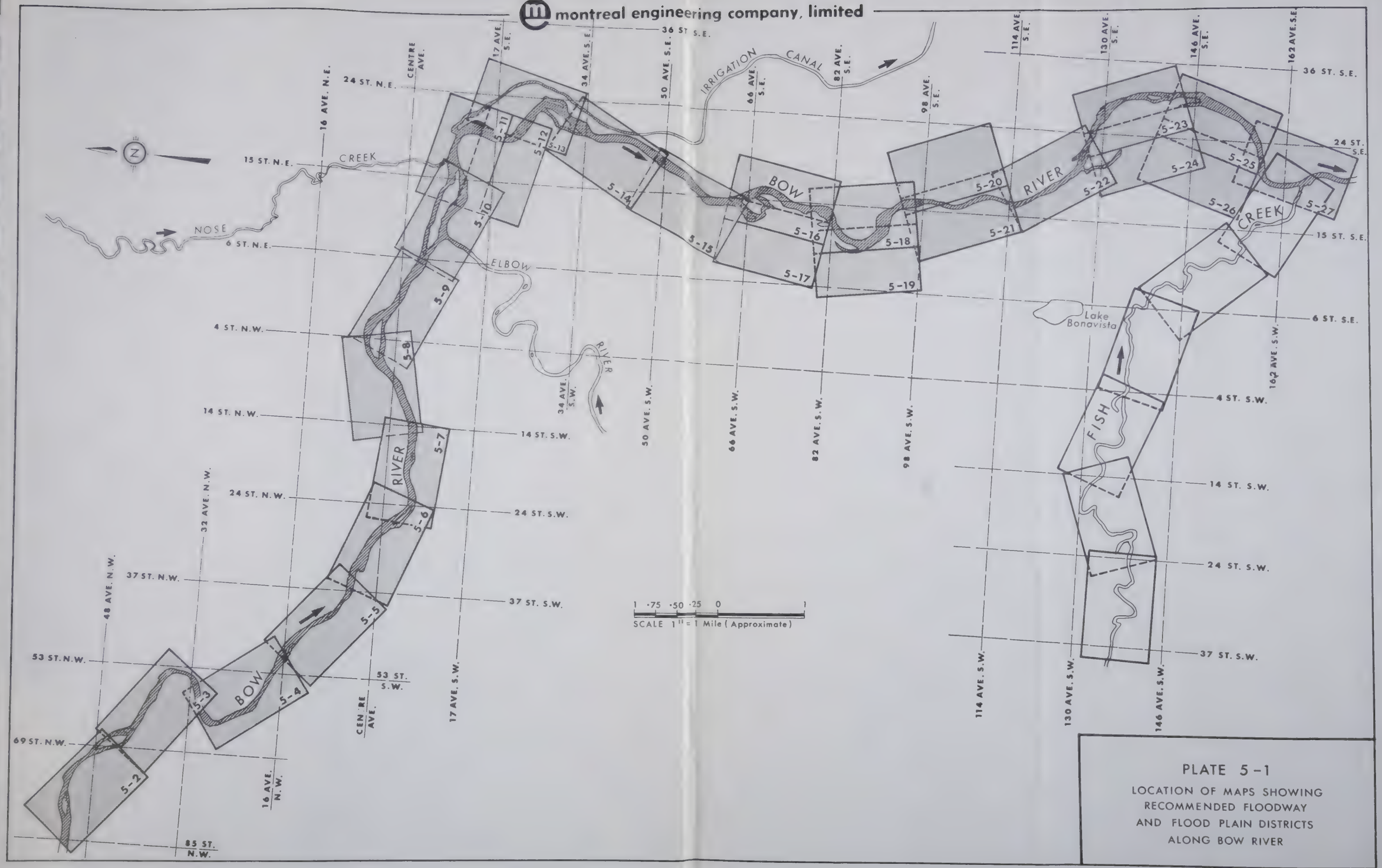


PLATE 5-1

LOCATION OF MAPS SHOWING
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
ALONG BOW RIVER

NOTES

1 – ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-2

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS
85 th ST. N.W. TO 69 th ST. N.W.

montreal engineering company, limited

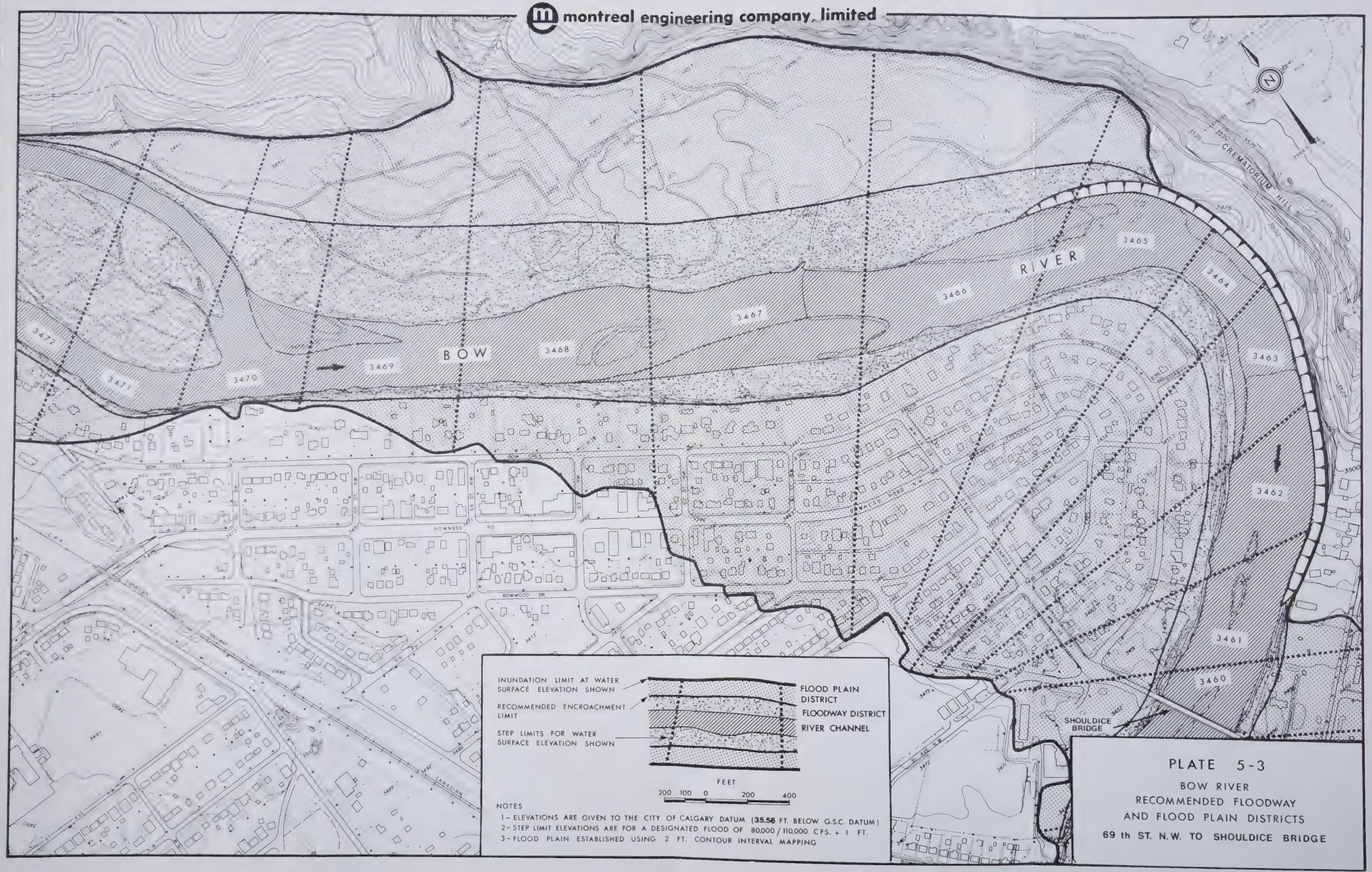


PLATE 5-3

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
69 th ST. N.W. TO SHOULDICE BRIDGE

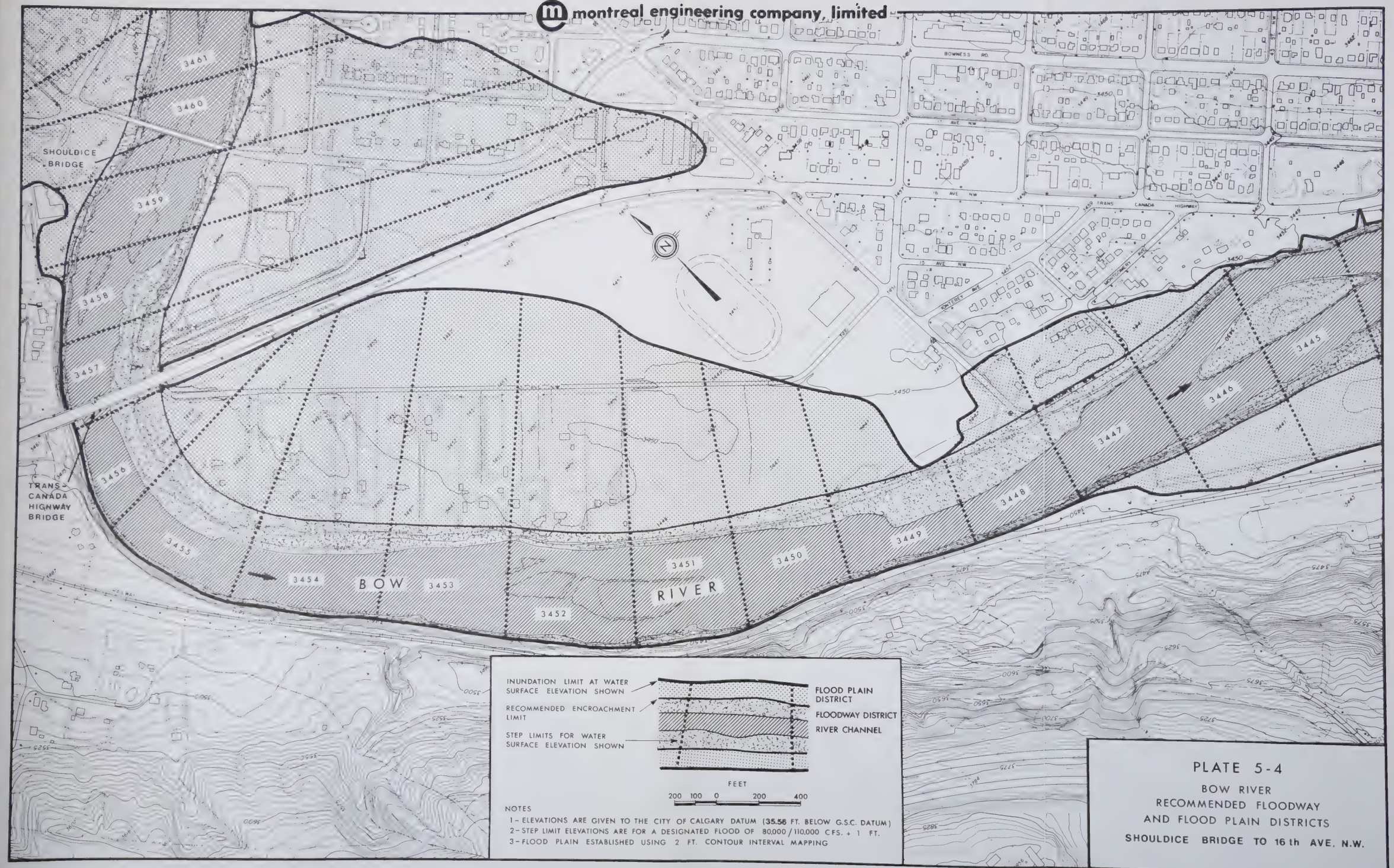
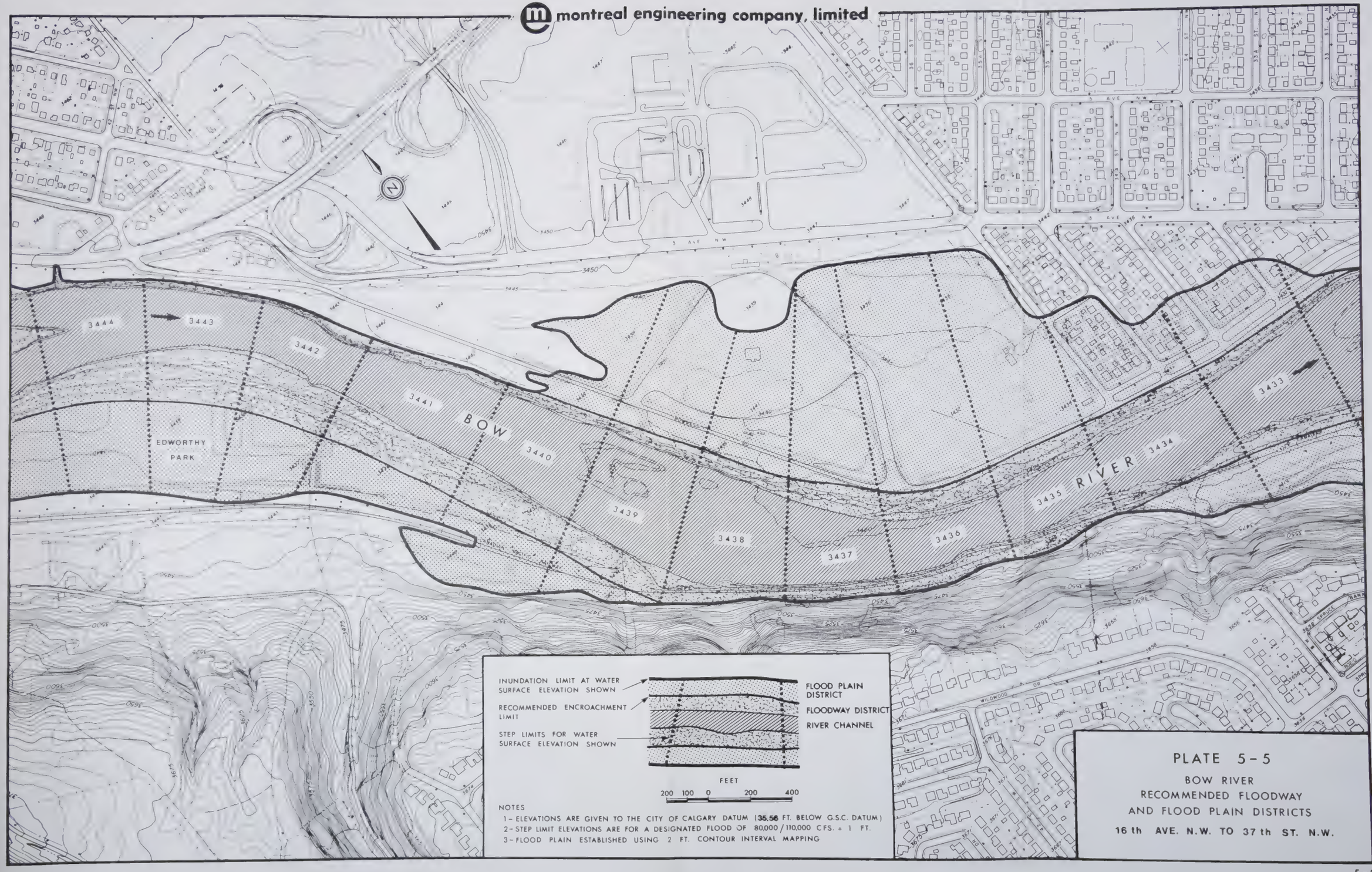


PLATE 5-4

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
SHOULDICE BRIDGE TO 16th AVE. N.W.



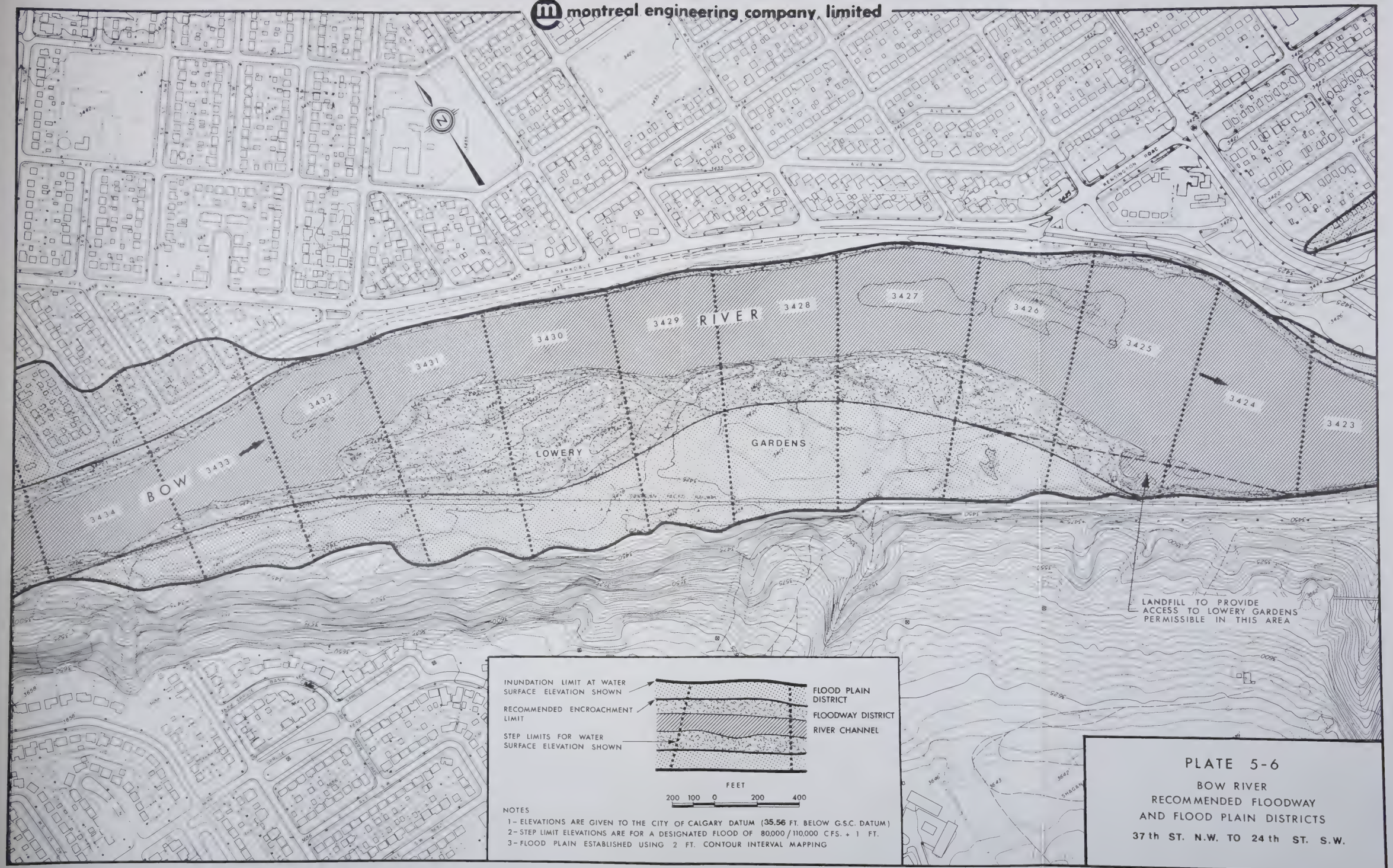
NOTES

1 – ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5 – 5

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS

16 th AVE. N.W. TO 37 th ST. N.W.



NOTES

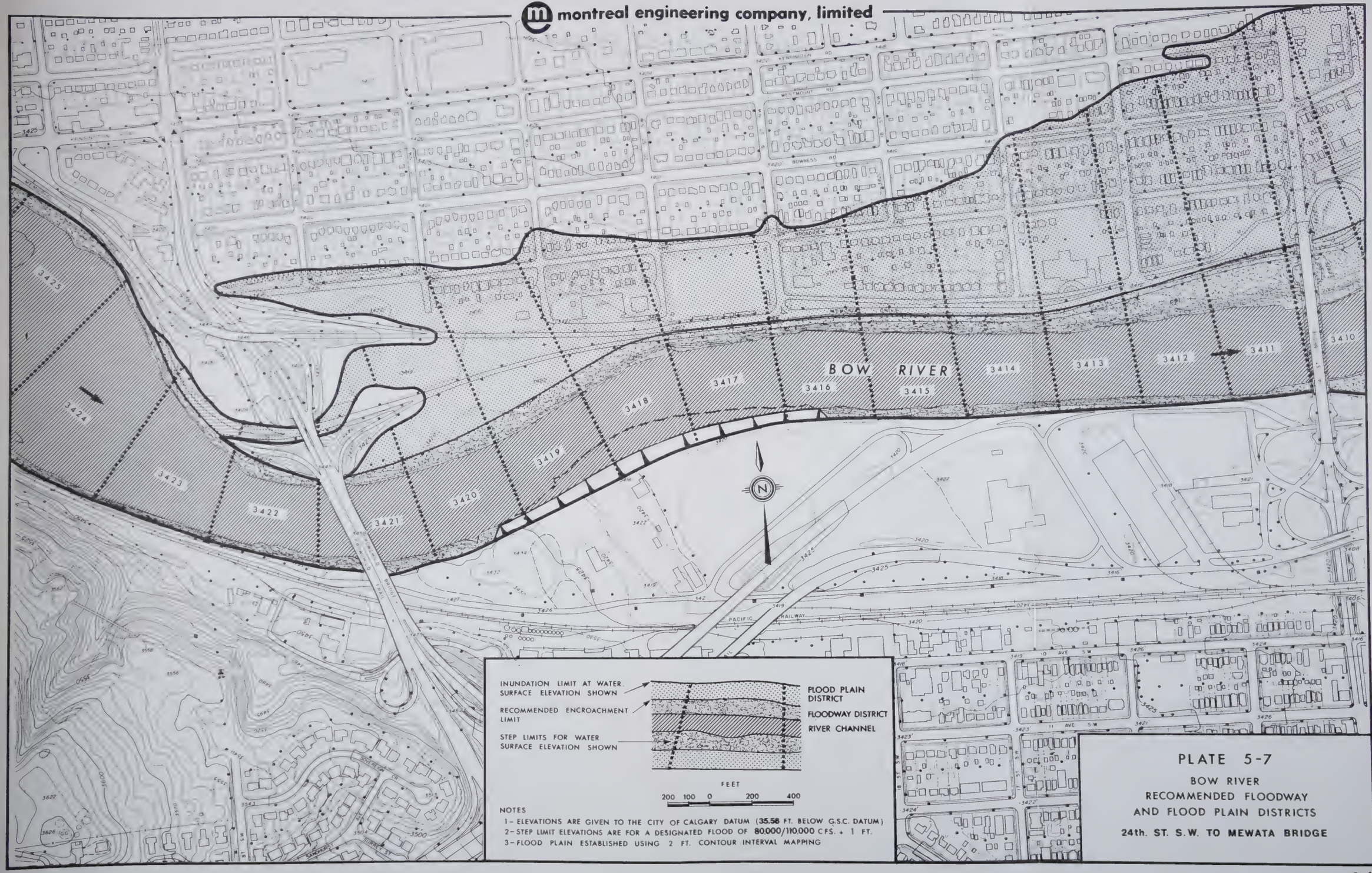
1 – ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 CFS. + 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-6

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS

37 th ST. N.W. TO 24 th ST. S.W.

montreal engineering company, limited



NOTES

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2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000/110,000 C.F.S. ± 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-7

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS

24th. ST. S.W. TO MEWATA BRIDGE

montreal engineering company, limited
RILEY PARK
3404
3399
3400
3401
PRINCE'S ISLAND
RIVER
3402
BOW
3403
3398
3405
3406
3407
3408
3410
3409
KENSINGTON RD
GLADSTONE
BURNSLEY
MEMORIAL
LOUISE BRIDGE
14 ST BRIDGE
PLATE 5-8
BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
MEWATA BRIDGE TO 4th. ST. N. W.

PLATE 5-9

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
4th. ST. S.W. TO 6th. ST. S.E.

montreal engineering company, limited

PLATE 5-10

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

6th. ST. S. E. TO 15th. ST. S. E.

montreal engineering company, limited

PLATE 5-11

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

15th. ST. S.E. TO CUSHING BRIDGE – LEFT BANK

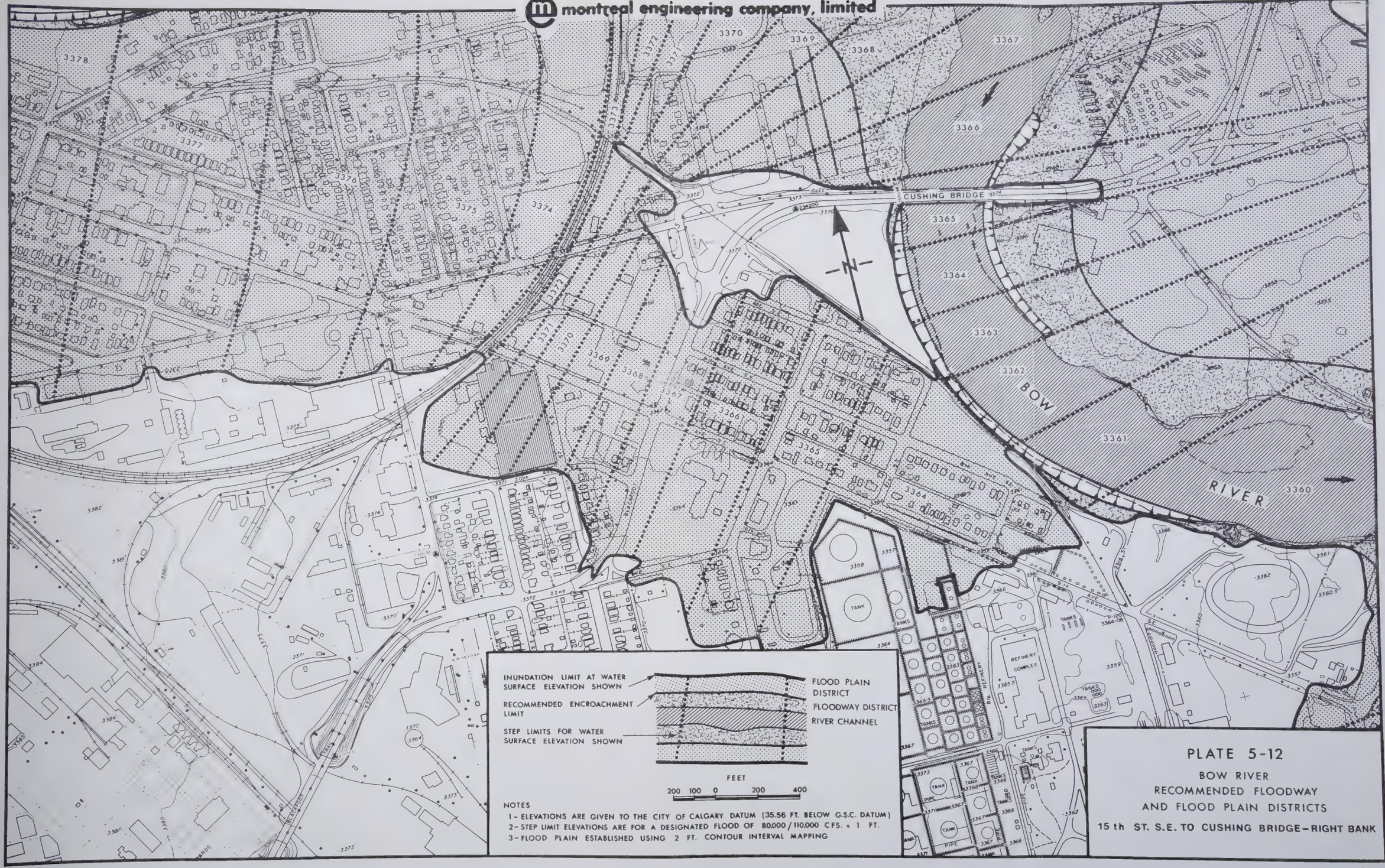

CUSHING BRIDGE
BOW
RIVER
N
INUNDATION LIMIT AT WATER SURFACE ELEVATION SHOWN
RECOMMENDED ENCROACHMENT LIMIT
STEP LIMITS FOR WATER SURFACE ELEVATION SHOWN
FLOOD PLAIN DISTRICT
FLOODWAY DISTRICT
RIVER CHANNEL
FEET
200 100 0 200 400
NOTES
1 - ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 - STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 - FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING
PLATE 5-12
BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
15 th ST. S.E. TO CUSHING BRIDGE - RIGHT BANK

PLATE 5-13

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
17th AVE. S.E. TO 32nd AVE. S.E.

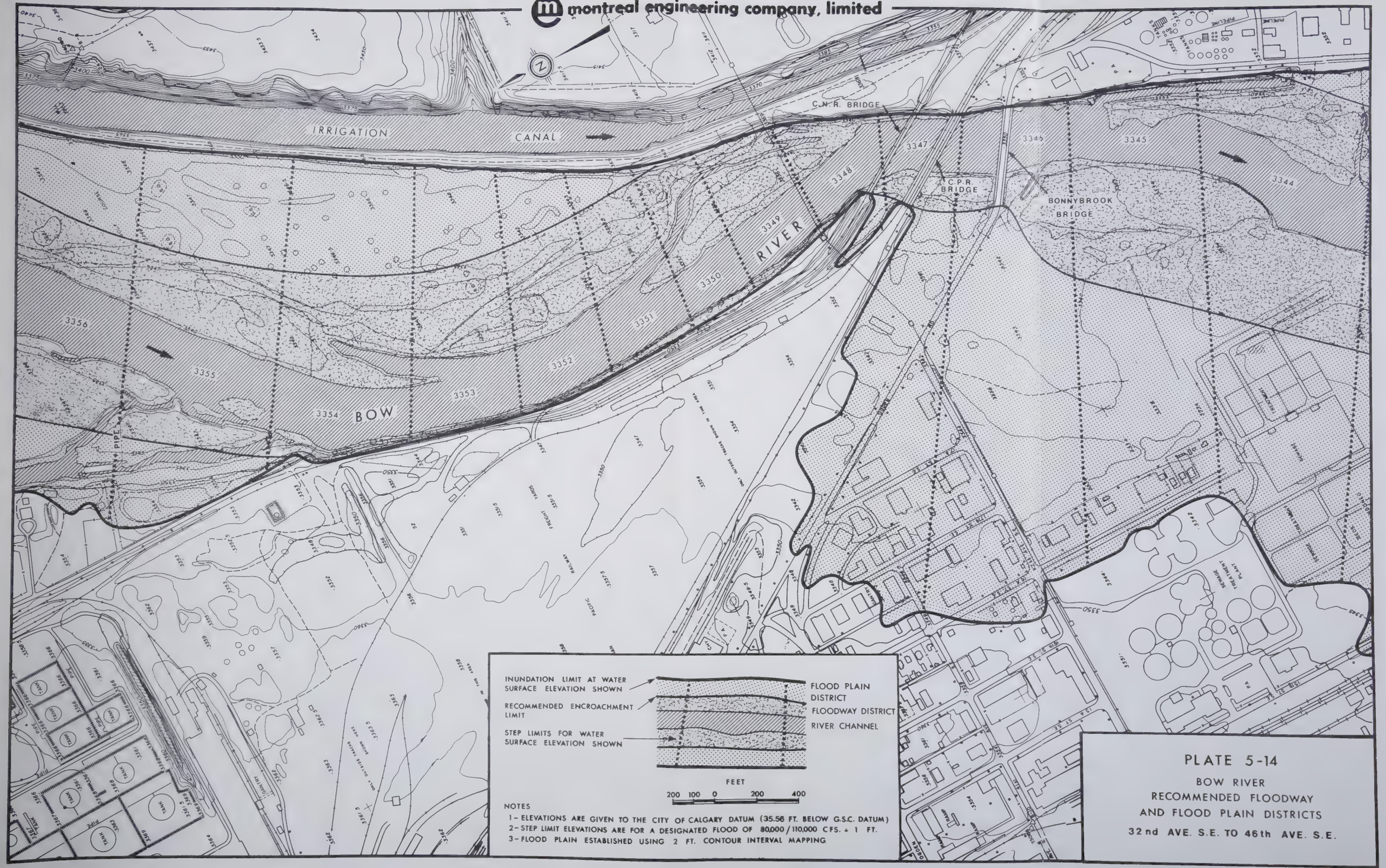

IRRIGATION CANAL
C.N.R. BRIDGE
C.P.R. BRIDGE
BONNYBROOK BRIDGE
BOW RIVER
PIPE
INUNDATION LIMIT AT WATER SURFACE ELEVATION SHOWN
RECOMMENDED ENCROACHMENT LIMIT
STEP LIMITS FOR WATER SURFACE ELEVATION SHOWN
FLOOD PLAIN DISTRICT
FLOODWAY DISTRICT
RIVER CHANNEL
FEET
200 100 0 200 400
NOTES
1- ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2- STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3- FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-14

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
32nd AVE. S.E. TO 46th AVE. S.E.

PLATE 5-15

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

46th. AVE. S.E. TO 64th. AVE. S.E.

PLATE 5-16

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

64th. AVE. S.E. TO 80th. AVE. S.E. – LEFT BANK

montreal engineering company, limited

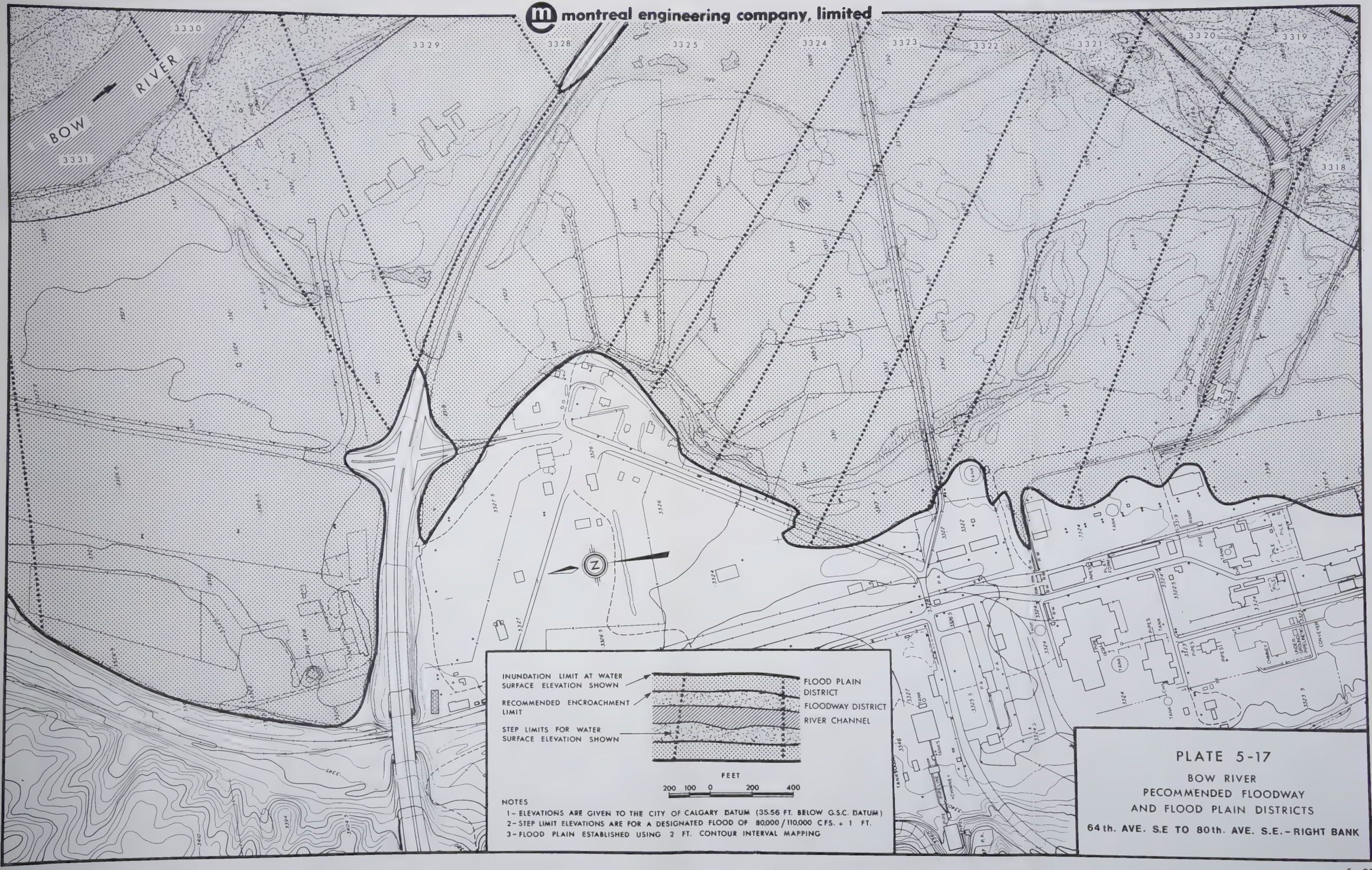

BOW RIVER
INUNDATION LIMIT AT WATER SURFACE ELEVATION SHOWN
RECOMMENDED ENCROACHMENT LIMIT
STEP LIMITS FOR WATER SURFACE ELEVATION SHOWN
FLOOD PLAIN DISTRICT
FLOODWAY DISTRICT
RIVER CHANNEL
FEET
200 100 0 200 400
NOTES
1 - ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 - STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 - FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-17

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

64th. AVE. S.E TO 80th. AVE. S.E. - RIGHT BANK

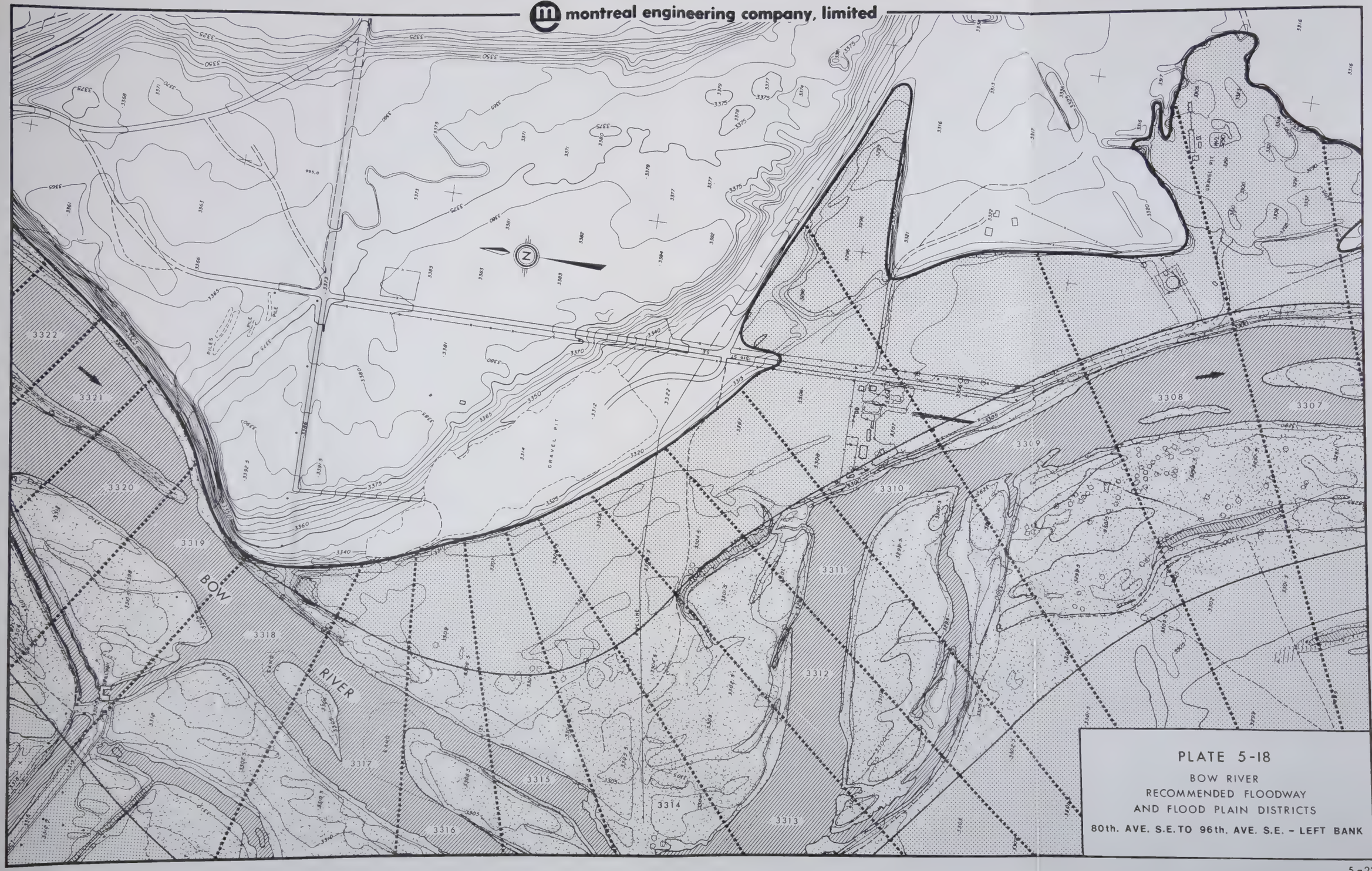
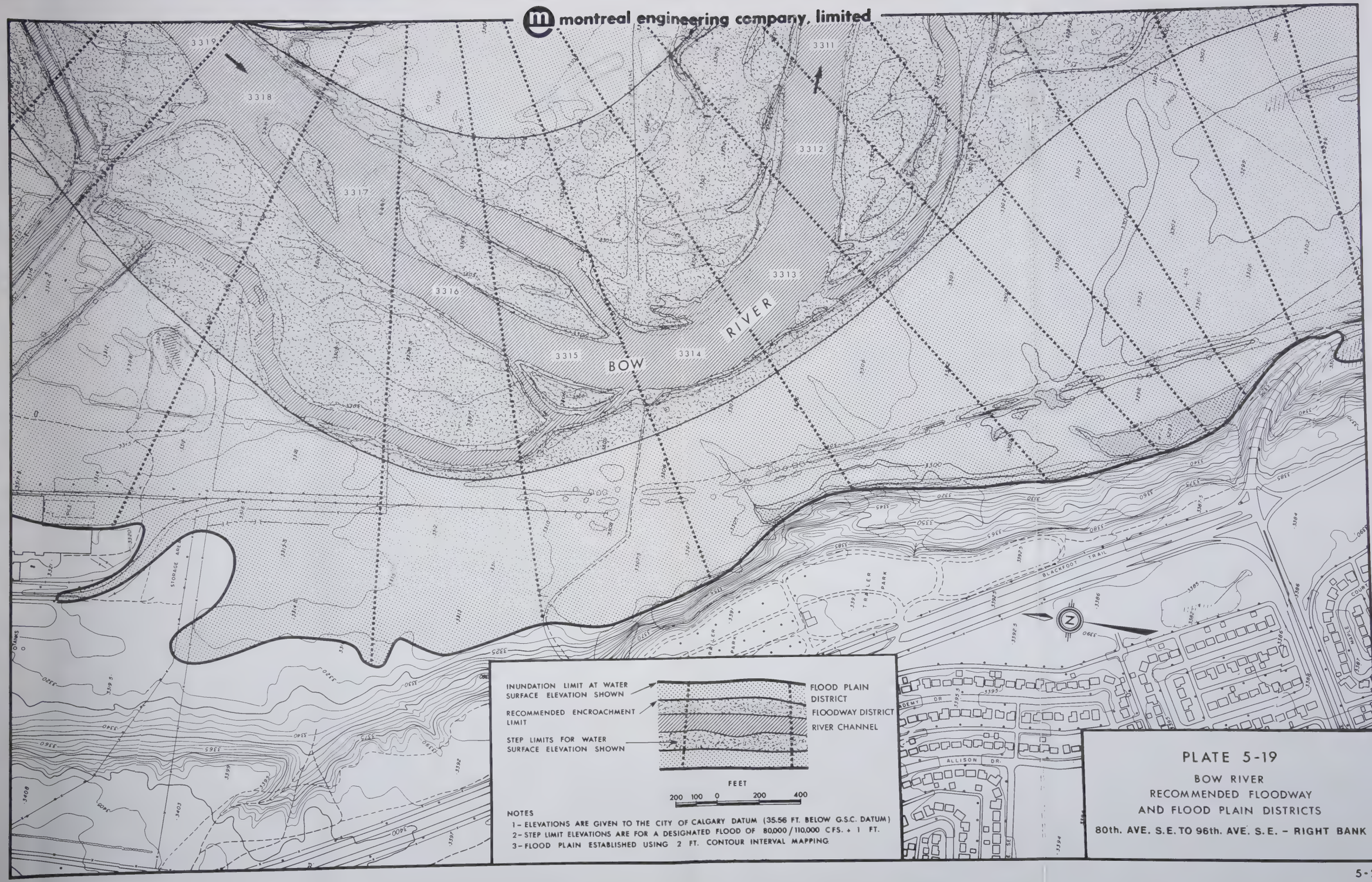


PLATE 5-18

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

80th. AVE. S.E. TO 96th. AVE. S.E. – LEFT BANK



NOTES

1 – ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-19

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS

80th. AVE. S.E. TO 96th. AVE. S.E. – RIGHT BANK

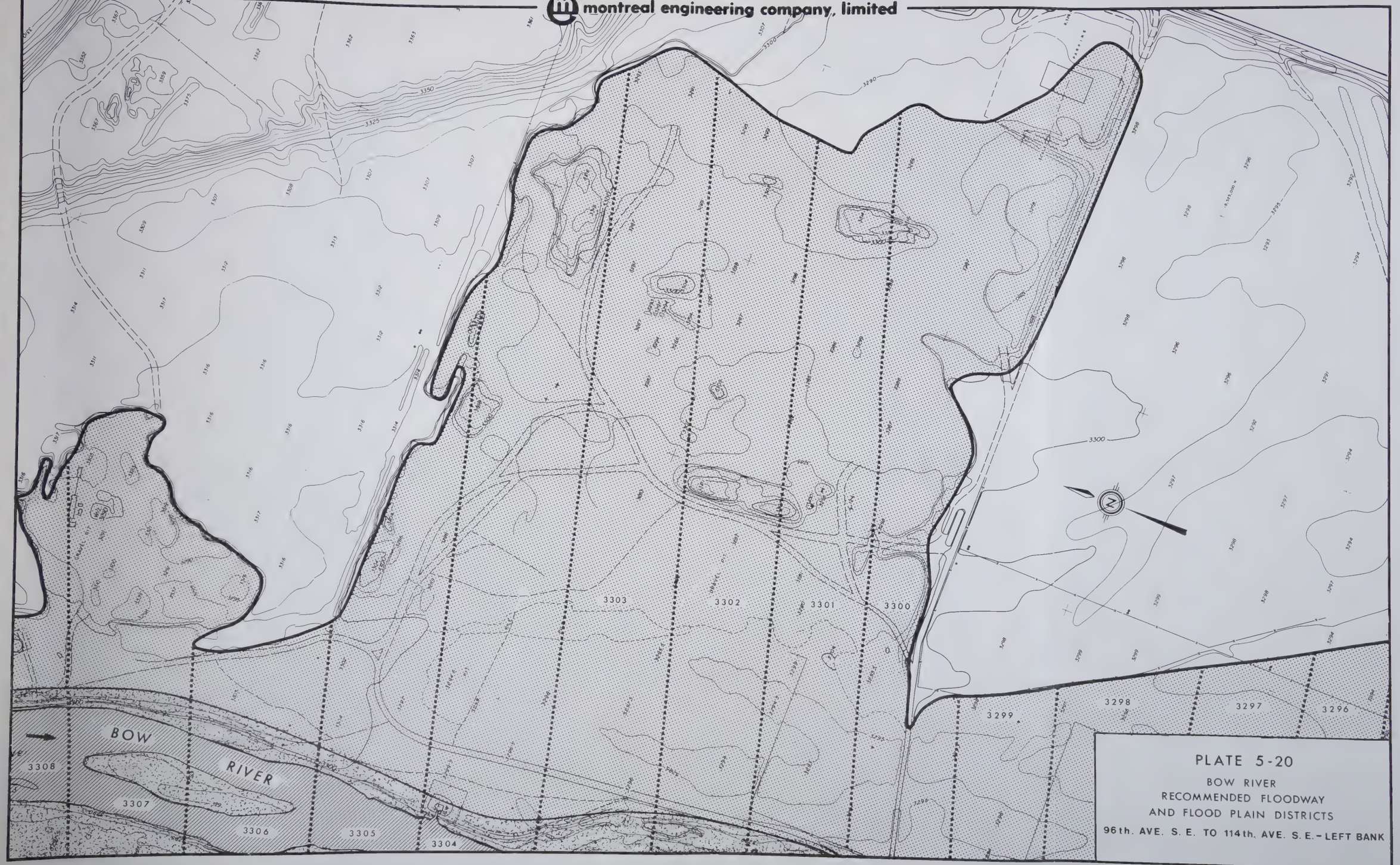
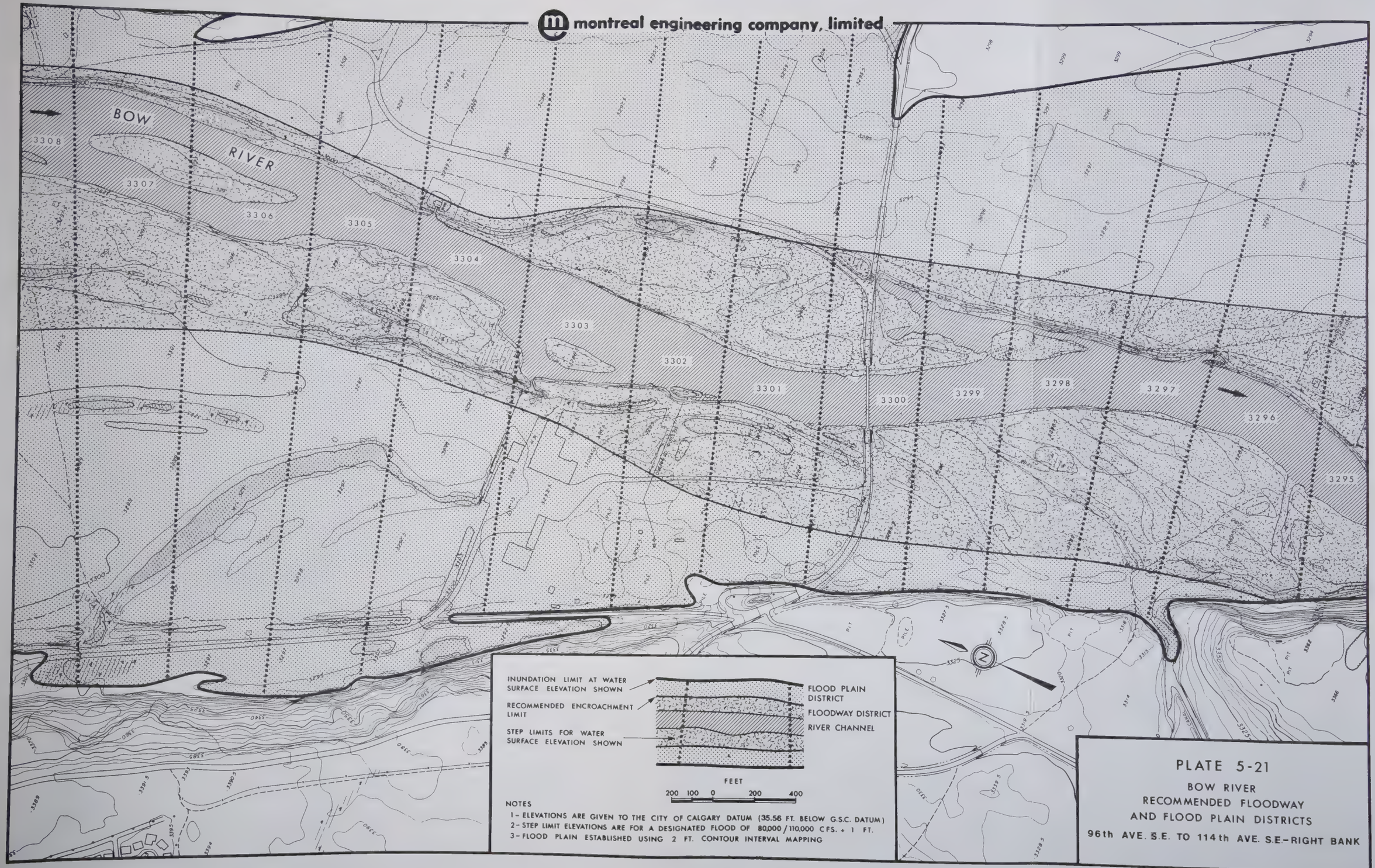


PLATE 5-20

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
96th. AVE. S. E. TO 114th. AVE. S. E. - LEFT BANK

montreal engineering company, limited



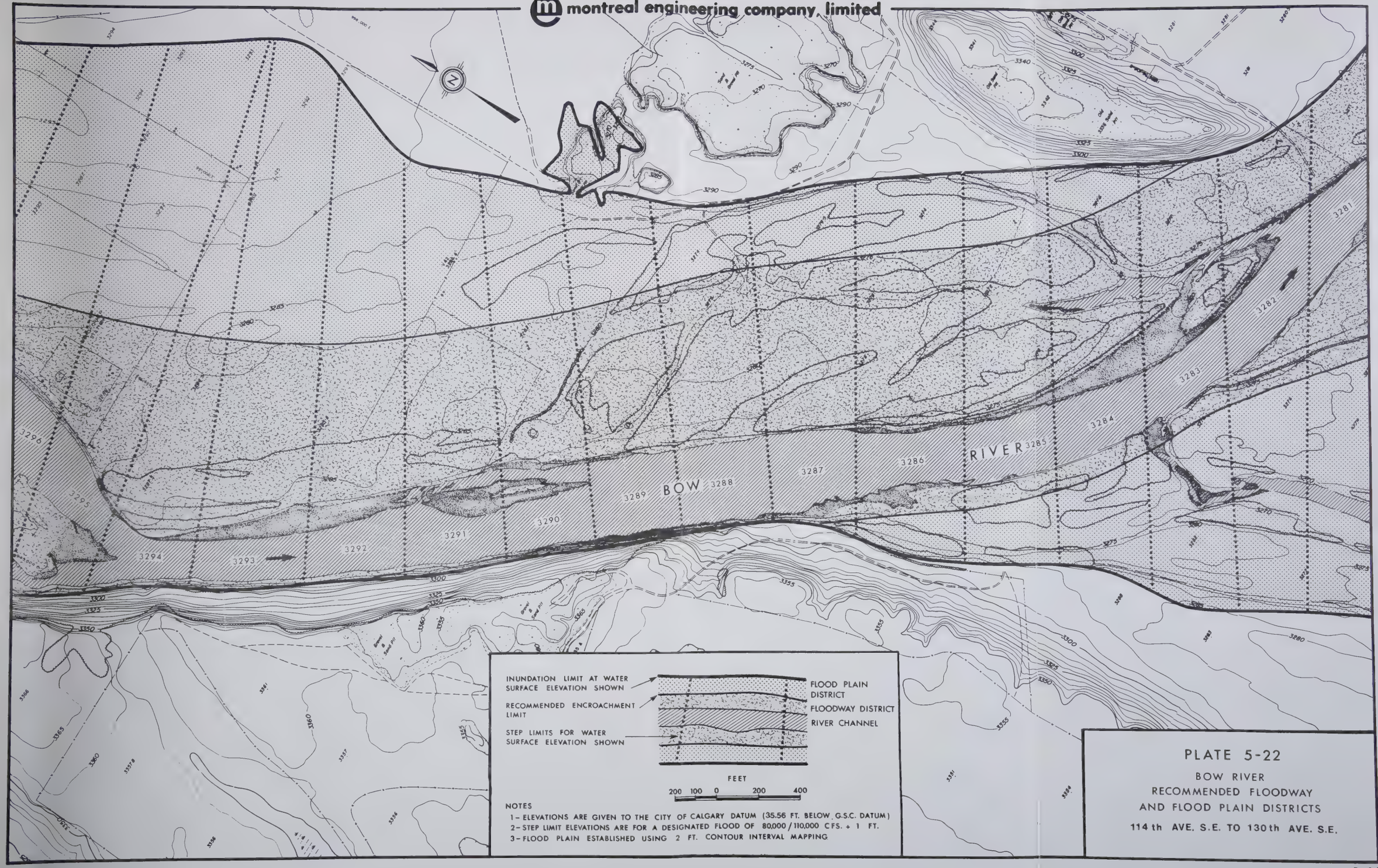
NOTES

1 - ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 - STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 - FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-21

BOW RIVER
RECOMMENDED FLOODWAY AND FLOOD PLAIN DISTRICTS

96th AVE. S.E. TO 114th AVE. S.E. - RIGHT BANK



NOTES

1 – ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 – STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 – FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING

PLATE 5-22

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
114 th AVE. S.E. TO 130 th AVE. S.E.

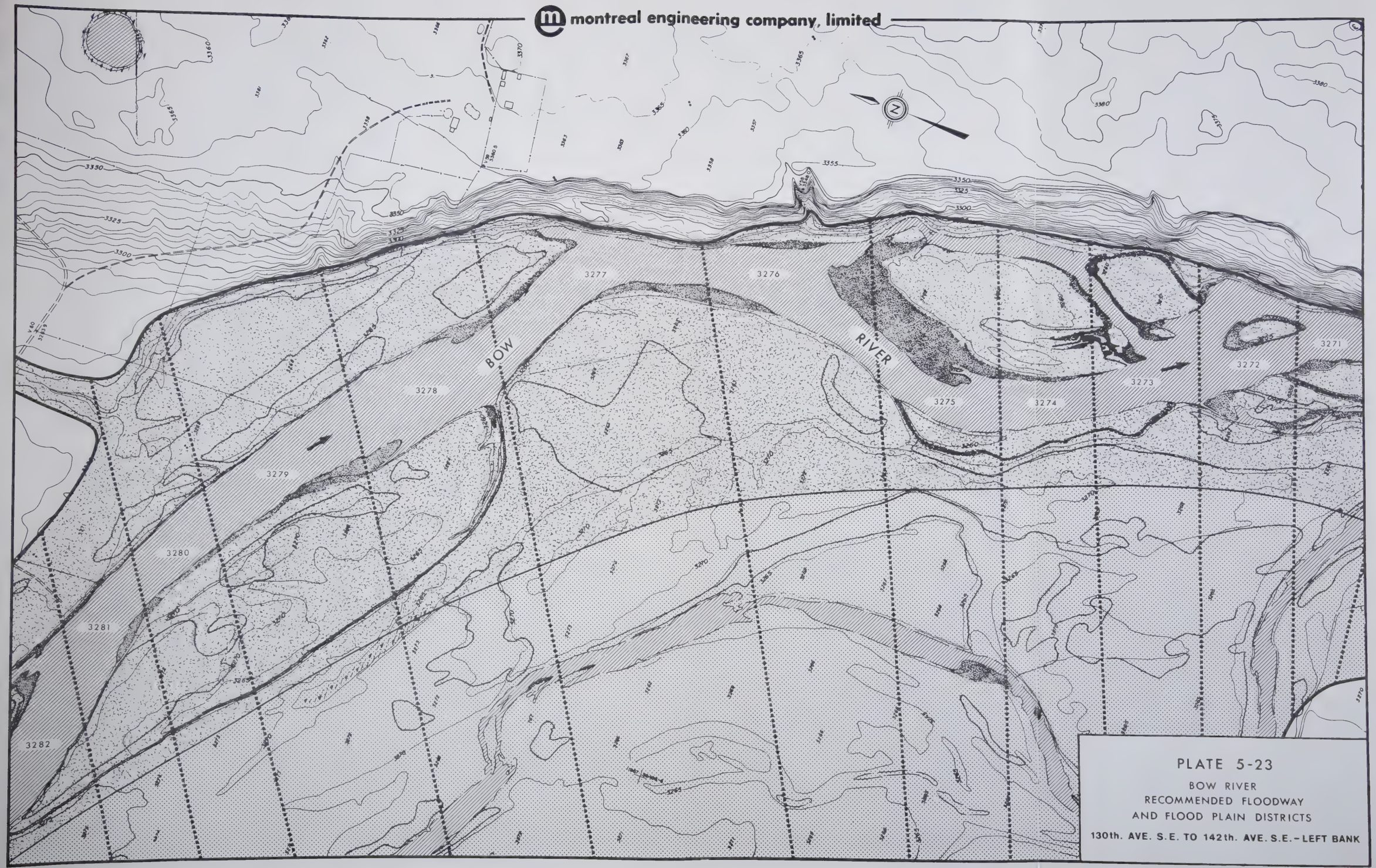
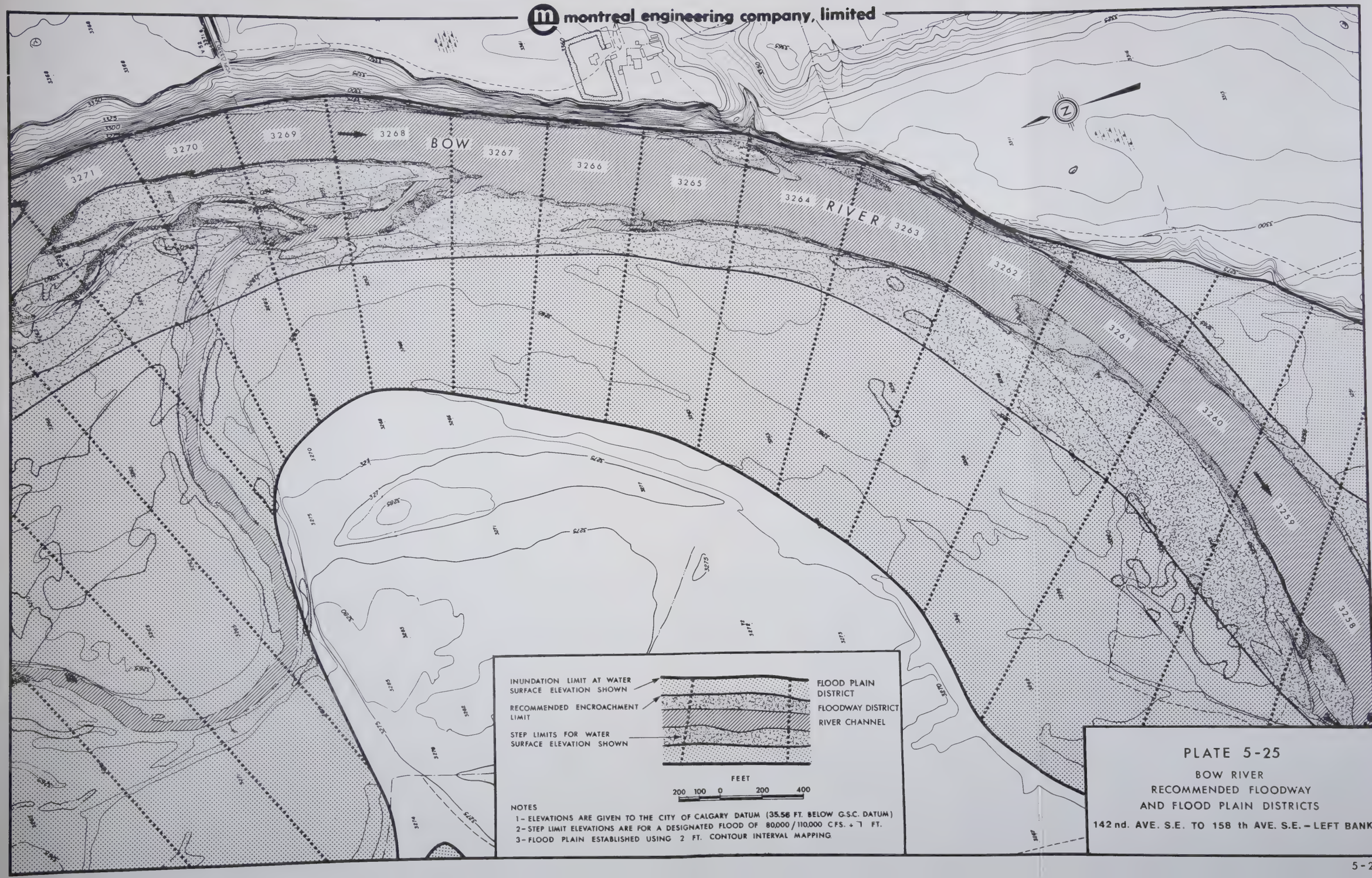


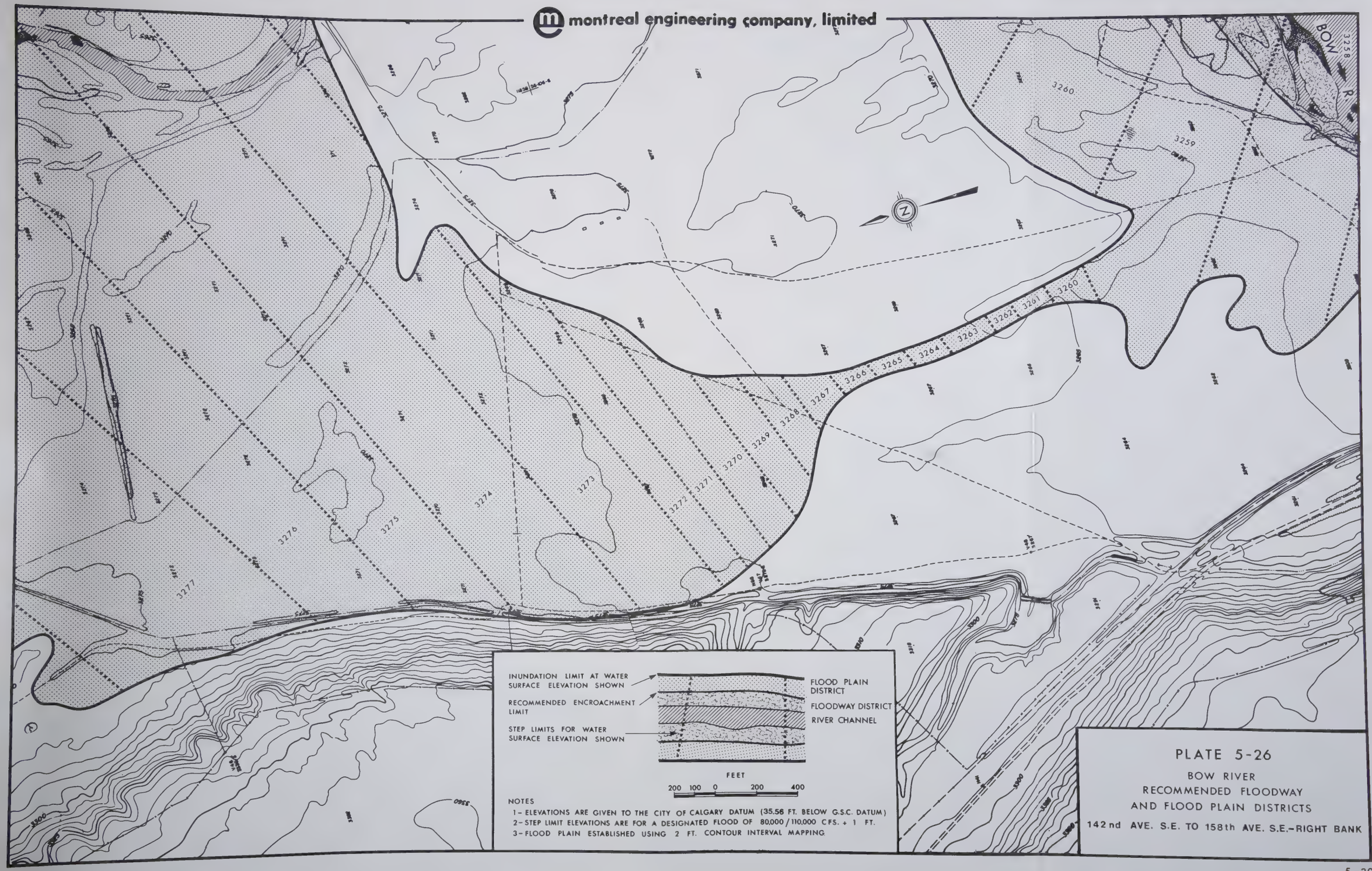
PLATE 5-23

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

130th. AVE. S.E. TO 142th. AVE. S.E. – LEFT BANK

montreal engineering company, limited
BOW R.
3282
3281
3280
3279
3278
3277
3276
3275
3274
3273
3272
3271
PLATE 5-24
BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
130th. AVE. S.E. TO 142th. AVE. S.E. – RIGHT BANK


montreal engineering company, limited
BOW
RIVER
3271
3270
3269
3268
3267
3266
3265
3264
3263
3262
3261
3260
3259
3258
INUNDATION LIMIT AT WATER SURFACE ELEVATION SHOWN
RECOMMENDED ENCROACHMENT LIMIT
STEP LIMITS FOR WATER SURFACE ELEVATION SHOWN
FLOOD PLAIN DISTRICT
FLOODWAY DISTRICT
RIVER CHANNEL
FEET
200 100 0 200 400
NOTES
1 - ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2 - STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000 / 110,000 C.F.S. ± 1 FT.
3 - FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING
PLATE 5-25
BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
142 nd. AVE. S.E. TO 158 th AVE. S.E. - LEFT BANK


BOW R.
3258
3260
3259
3260
3261
3262
3263
3264
3265
3266
3267
3268
3269
3270
3271
3272
3273
3274
3275
3276
3277
3280
3300
3000
INUNDATION LIMIT AT WATER SURFACE ELEVATION SHOWN
RECOMMENDED ENCROACHMENT LIMIT
STEP LIMITS FOR WATER SURFACE ELEVATION SHOWN
FLOOD PLAIN DISTRICT
FLOODWAY DISTRICT
RIVER CHANNEL
FEET
200 100 0 200 400
NOTES
1- ELEVATIONS ARE GIVEN TO THE CITY OF CALGARY DATUM (35.56 FT. BELOW G.S.C. DATUM)
2- STEP LIMIT ELEVATIONS ARE FOR A DESIGNATED FLOOD OF 80,000/110,000 C.F.S. + 1 FT.
3- FLOOD PLAIN ESTABLISHED USING 2 FT. CONTOUR INTERVAL MAPPING
PLATE 5-26
BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS
142nd AVE. S.E. TO 158th AVE. S.E.-RIGHT BANK

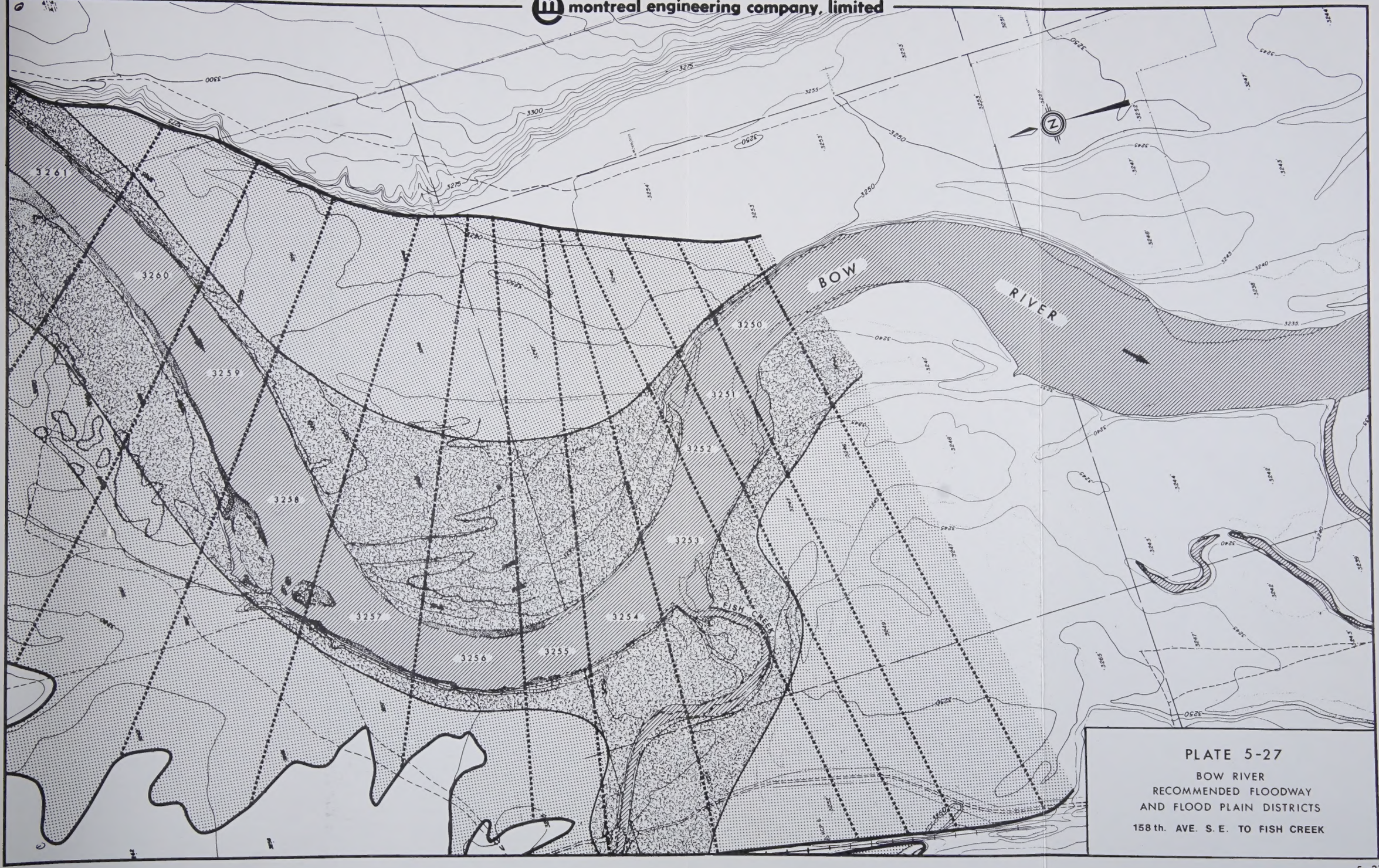


PLATE 5-27

BOW RIVER
RECOMMENDED FLOODWAY
AND FLOOD PLAIN DISTRICTS

158th. AVE. S.E. TO FISH CREEK